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Tata Energy Research Institute

Contents

Plant Maintenance Management in Sugar Industry

A Thiagrajan
NPC

PLANT MAINTENANCE MANAGEMENT IN SUGAR INDUSTRY

1.0 INTRODUCTION

Proper Maintenance Management has been one of the important elements towards overall improvement of the Sugar industry, specifically in terms of energy and environment effectiveness. It has been observed from performance parameters that maintenance productivity has direct relation to energy consumption and also environment performance. This article describes the latest developments in plant maintenance management that can play stellar role in energy and environment management of Sugar Industries

2.0 ROLE OF MAINTENANCE IN ENERGY CONSERVATION & ENVIRONMENT PRESERVATION

Conservation of energy and compliance with environmental regulations have become increasingly important due to steep increase in energy consumption & environmental pollution as the indutries are going in for large scale capacity expansion and modernisation. Apparently, it is being felt that it is the responsibility of the top management. But, it depends much on how effectively the plant is operated and maintained and hence it is the Operation & Maintenance Departments who can substantially contribute to energy conservation and environment preservation.Often "Maintenance" is overlooked as "*Necessary Evil*" and is considered as *Consumable rather than Producible* as there is a firm belief that maintenance costs money But maintenance not carried out costs even more money. Proper planning and appropriate maintenance strategy can lead to increased capacity utilization & substantial savings The key words for improving Total Systems Performance of a Sugar industry namely, Production, Energy Consumption, Quality, Delivery, Safety & Environment, Cost and Morale have a very close relation with maintenance of the plant.

3.0 EFFECTIVE MAINTENANCE MANAGEMENT STRATEGIES IN SUGAR INDUSTRIES

The development in maintenance management has been based on technological advancements from conventional Breakdown Maintenance to Preventive Maintenance, Predictive Maintenance, and Proactive Maintenance Strategies. Different management theories like Reliability Based Maintenance and Total Productive Maintenance (TPM) approach the selection and utilization of these technologies from different perspectives

Breakdown Maintenance is possibly the weakest strategy as it is bound to increase down time, energy consumption, production loss, machine component replacement and also may be the root cause of many safety and environmental disasters. Due to these deficiencies, it is possibly the last choice of a maintenance management function, however still practised many a times rather by compulsion due to many limitations. While it may not be possible to completely eliminate

breakdown maintenance, it would be prudent to limit it to applications where the consequence of failure would be negligible for plant availability, energy loss and environment & safety.

Preventive maintenance is widely being practiced now-a-days in Sugar Industry. Preventive maintenance emphasizes on carrying out periodically scheduled activities on the equipment either to avoid the breakdowns or identify the condition well before it can turn into a breakdown. For example, simple preventive maintenance activity like regular cleaning of motors can give rise to considerable savings in heat losses and also failure of motor windings. Rolling element bearings in Pumps Compressors would be changed, irrespective of whether they are damaged or not. Similarly, lubricating oil in the gear boxes would be changed after a predetermined period of working hours. However even preventive maintenance strategy has pitfalls that it is not easy to decide upon such intervals of inspection and replacement Too frequent Preventive Maintenance activities lead to wastage of production time as well as unnecessary replacement of machine parts and components. Moreover, there is always possibility of human error while performing such inspections and maintenance work and the material consumption may be more than ideal or the human intervention in the equipment technology may aggravate the failure rates rather than obviate it.

Predictive maintenance using Condition Monitoring Techniques can to a large extent, solve the deficiencies of both breakdown and preventive maintenance strategies. Even indirect preventive maintenance, known as subjective condition monitoring using human senses, would be able to identify failures in advance and aid in taking corrective action. Both simple aids and instrumentation enhance the predictive maintenance capabilities to solve many equipment failures, energy losses, environment and safety problems.

Proactive maintenance strategy advances over the predictive maintenance technology in its ability to identify machinery deviation even before it begins to develop. The ability of some monitoring instrumentation to track the hydraulic oil contamination even at the ppm trace levels and eliminate them using cleaning equipment simultaneously is an example of proactive maintenance strategy.

4.0 PREDICTIVE MAINTENANCE & CONDITION MONITORING

Predictive Maintenance is carrying out preventive maintenance at what may be irregular intervals, but determining these intervals by the actual condition of the machine For such condition-based maintenance to be possible, it is essential to have knowledge of the machine condition and its rate of change with time The main function of condition monitoring is to provide this knowledge. The knowledge may be obtained by selecting a suitable parameter for measuring deterioration, and recording its value at intervals Assessing the trend of this measurement can give a useful lead time in warning of incipient machine failure and in planning and organisation of maintenance work.

4.1 Condition Monitoring With Simple Aids

It is wrong notion among us that for carrying out objective condition monitoring, we shall always require complicated instruments Actually there are methods available and methods could be developed to do the same with simple aids. A few examples of using simple aids for condition monitoring in sugar industry are given below.

Example 1: For monitoring the temperature rise of bearings and motors, use can be made of temperature tapes. The tapes are available for different temperature bands. The tape carries windows for different temperature levels within the band. The tape is to be pasted on the surface which needs temperature monitoring. Once a particular temperature level has reached, the corresponding window changes colour, mostly black.

Example 2: V-belts drives used in various rotating machineries like pumps, compressors and blowers can be monitored for right tension using simple aids known as 'Tensiometers'. The instrument is capable of applying a predetermined displacement to the belt and quantifiably measure the force required to produce the same thus predicting whether the belt drive is having proper tension or not.

Example 3: In a flexible pin and bush type of coupling, the wear of the rubber bushes can be easily checked by marking the coupling halves. As the coupling is loaded, the marks separate. As the rubber bush wears, dimension 'A' (the distance of separation of the marks) increases. A maximum value of dimension 'A' can be set as a limit when the rubber bushes are to be replaced. Dimension 'A' can inspected when the coupling is running with the help of a stroboscope.

Example 4: To monitor the condition of lube oil in service a simple aids known as 'Viscosity comparator' and 'Moisture Test Kit' can be used. The viscosity comparator uses the principle of flow differences due viscosity variations between used oil and fresh oil. The moisture test kit finds out the percentage of moisture in the lubricating oil using chemical methods by reacting Calcium Hydride with the moisture present in the oil in a small reacting bottle. The resultant hydrogen emission is used to displace carrier fluid mostly kerosene and measuring the moisture percentages.

4.2 Condition Monitoring Using Modern Advanced Instruments

In process plants like the modern sugar industry, it is also required in addition to use periodic and on -line condition monitoring techniques and systems using sophisticated instrumentation to ensure optimum plant availability and personal safety. Of course, heavy damage to the high speed giant rotating machines can also be prevented by using these techniques. The different techniques and systems used in this category are explained below:

4.2.1. Vibration/Signature Analysis

This is very advanced technique and is very useful for on-line monitoring of rotating machines like diesel generators, pumps, compressors, gearboxes etc. This technique should be used for critical machines only because it is a costly technique and it requires lot of skill to interpret and analyze the readings. The characteristics used to diagnose the incipient failures and also the nature of failures are amplitude (peak to peak displacement, velocity and acceleration) and frequency of vibration. The principle is that as failure develops, the amplitude of vibration increases and depending on nature of failure, a particular frequency of vibration is generated.

The Sugar industry should have an active programme involving routine noise and vibration measurement, analysis and control on important production and operating machinery to avoid

unscheduled shut downs and costly failure. All machines vibrate and make noise - because of mechanical defects, large and small. Excessive vibration or a substantial increase in the normal vibration or noise level of a machine is a warning that there is a deterioration in the component function. There could be many reasons for high vibration. Some of these are:-

a. Unbalance of rotating parts
b. Misalignment of couplings and bearings
c. Mechanical looseness
d. Bad antifriction bearings
e. Bent shafts
f. Worn, eccentric or damaged gears
g. Bad drive belts and drive chains
h. Hydrodynamic forces in case of Pumps
i. Aerodynamic forces in case of Fans
j. Electromagnetic forces
k. Oil whirl

A lot can be learned about a machine's condition and mechanical problems by simply noting its vibration characteristics in terms of frequency, displacement, velocity, acceleration and phase. When analysing a machine's vibration to pinpoint a particular problem, it is essential to know the vibration frequency. Knowing the frequency allows us to identify which part is at fault and what the problem is. The displacement, velocity and acceleration characteristics of vibration are measured to determine the amount or severity of the vibration. Displacement and velocity measurements will be sufficient for majority of Sugar machinery. Acceleration measurement will be more relevant in case of gear boxes.

Signature Analysis

In many situation a change in the vibration of one frequency component, which is indicative of trouble, can be masked by a more dominant but acceptable vibration at another frequency. In such circumstances frequency analysis is essential. In the frequency analysis process an electrical filter network is employed to reject part of the frequency spectrum whilst allowing another part to pass through the filter. Several sophisticated vibration analysers and signature plotters are available these days. These can analyse and represent the vibration signal in terms of:-

a. Amplitude versus frequency,
b. Amplitude versus time,
c. Amplitude versus frequency versus time.
d. Amplitude and phase versus rpm.

The results of this type of analysis, presented as a plot of amplitude versus frequency etc., is referred to as the vibration signature of a machine. Interpretation can be made out of these signatures in order to find out the possible cause of high vibration. Generally, vibration signatures will be recorded soon after commissioning a new machine, when it is running satisfactorily. These signatures taken in the beginning are referred to as "baseline signatures". Future comparison of vibration readings will be made against these baseline signatures. Once a problem has been

identified through analysis, the obvious next step is correction, for which many balancing and other maintenance techniques are available. In the case of gearbox problems, in addition to the spectrum analysis, cepstrum analysis would also be made use of.

Gear Box Problem Diagnosis

Vibration spectrum analysis alongwith cepstrum analysis would be an effective way of diagnosing gear box problems. The gear box spectrum will contain the meshing frequencies (the number of gear teeth times the rpm of the faulty gear), their harmonics, overtones, side bands, etc. The various problems of gear failure such as excessive gear wear, improper adjustment of backlash, gear tooth inaccuracies, faulty lubrication, gear eccentricity etc., can be detected through the Cepstrum Analysis.

4.2.2. Shock Pulse Method (SPM)

This is very useful and economically viable method to monitor operating condition of antifriction bearings. In fact this technique was developed after observing that the diagnosis of operating condition of antifriction bearings with vibration analyser is extremely difficult as the amplitude is unsteady and frequency is very high. Shock pulse method is based on the principle that when a surface defect is developed on the rolling element or the races, a mechanical shock will be generated. This shock intensity is measured with shock pulse meter in terms of dB to monitor the operating condition of antifriction bearings. A correlation is established between bearing condition and rise in shock value level (SVL) relative to the normal shock value. The interpretation of the results is quite easy and the instrument is very portable.

Rise in SVL (dBN)	Bearing condition
less than 20	Good condition
15-25	Undamaged bearing lacking lubrication or improperly installed
20-35	Damage developing
35-50	Visible damage
50-60	Rise of breakdown

An examination of the reliability of ball and roller bearings showed that their service lives differed considerably. For the purposes of the test, a number of ball bearings were utilized under identical conditions. After a certain period of time, 10% of the bearings had broken down. However, it took twenty-five times as long for the last bearing to fail. If in the course of preventive maintenance, all ball bearings were to be replaced after a period of time when 10% of the bearings tend to fail, the potential lives of the remaining 90% would be wasted. 90% of the bearings would be replaced too soon, and yet there would be cases of unforeseen bearing failure. On the other hand, if the

condition of each bearing is established during operation by continuous inspection and replacement is carried out only when it appears justified, we achieve the following advantages:

1. Fewer bearing replacements
2. Reduced bearing consumption
3. Increased operational reliability
4. Less need for planned stoppages for bearing replacements

Rolling-element bearings are used in sugar machinery in greater quantities and they are one of the most common types of failure in the sugar industry. The probable reasons for failure are excessive load, metallurgical failure, lack of lubrication, use of contaminant lubricants, improper mounting and the completion of the safe working life. The downtime cost is very high in case these bearings fail during operation. At the same time, we can not afford to replace these bearings at fixed intervals due to high cost.

4.2.3. Spectroscopic Oil Analysis Procedure (SOAP)

SOAP is a technique to monitor condition of machines by analysing used oil samples. It is an indirect method. The principle of this technique is that it measures concentration of wear particles of different elements present in the used oil sample with the help of a 'Direct reading spectrometer'. The wear debris will be microscopic particles forming a homogeneous colloidal suspension in oil These particles are too small to be removed by filter. A normal wear rate may be established for a particular metal in a particular system Any condition which increases the friction between moving parts will accelerate the wear rate and thus be detected by SOAP.

4.2.4 Ferrography

Ferrography oil analysis enables a detailed examination to be made of the microscopic particles generated by wearing surfaces and so can yield valuable information about the condition of components The basic concept involves the magnetic separation of iron and steel (ferritic) wear debris from a lubricant and arranging it, according to particle size, on a glass slide for subsequent examination through a microscope The particle sizes may range from sub-micron to several hundred microns During severe wear, when failure is beginning, the deposit will change drastically, the total quantity of debris will increase, there will be a greater proportion of larger sizes and the maximum size will also increase

4.2.5. Thermography

This technique is based on measurement of infra-red radiation emitted by different materials at different temperatures The surface of the object to be monitored is scanned with a camera which produces a thermal pattern on a video screen corresponding to the temperature distribution. This helps in locating the hot spots because the intensity of light at each point of the screen depends on temperature at corresponding point on the object. The greatest advantage of thermography instrument is that the hot spots can be detected from a distance without requiring any contact with the object and a big area can be scanned very fast as from maintenance point of view we need to know only the hot spots and not the absolute temperature. Thermography is very useful to identify

failed refractory insulation conditions and also electrical transmission and distribution systems like cable boxes circuit breakers. transformer. contactors. insulators. etc The insulation strength of high voltage motor windings can also be monitored.

The monitoring system primarily consists of a high speed infrared scanner for measurement of the infrared radiations/heat emitted from a surface. a computer for analysis of temperature readings and a graphical display screen printer. Such a sophisticated system enables us to determine the state of lining coating insulations/joints etc and location. size & geometry of existing or developing hot spots.

4.2.6. Systematic Application Of Condition Monitoring

One of the problems of condition monitoring is the state of confusion generated by the wide variety of monitoring techniques Even within the field of vibration monitoring, there is a profusion of measurement methods each with its particular virtue. Each technique requires a special skill and understanding and some of the more useful techniques have been developed only in the last decade

The key feature of condition monitoring. whatever the technique in use. is the accumulation of data, which at the time of collection seem to have limited value. however. only when sufficient data are collected can normal condition and possible deviations be established and redundant data cease to be accumulated. Thus keeping records is essential to any monitoring programme. To keep paper work to a minimum the data recording system should be devised to provide the important information clearly to the decision maker Where possible the forms devised for collection of data should also serve to present the information necessary for decision making so that transfer of data is avoided For example where the trends in a monitored parameter are used to indicate plant condition it is useful for the data to be plotted directly onto graphs since the mind can absorb visually presented data more effectively than written data Unfortunately. in the early stages of a monitoring programme there is considerable redundancy in measurements. Only when experience of normal conditions and malfunctions has been obtained will the engineer be able to cut down on the number of measurements made The importance of recording all relevant particulars of the machine and of the monitoring equipment and tests cannot be over emphasized One of the most common difficulties encountered by the decision maker. when a monitoring technique detects a trend indicative of failure. is lack of data Where many machines are operated. consideration should be given to the advantages of computer data storage and presentation.

5.0 TOTAL PRODUCTIVE MAINTENANCE (TPM)

Technology oriented developments like condition monitoring as described above alone have failed to produce desired results It was felt that human participation is a vital element in achieving total improvements and hence led to practice of methodologies like TPM. Conceptually. TPM is departure from the "I Operate - You Fix" approach to "I Operate and I maintain" philosophy. It is implementation of productive maintenance by all employees. based on the principle of involvement of all in improving equipment performance from operators to top management. TPM takes on the challenge of Zero losses. meaning zero failures and zero defects. When there are no failures or defects, equipment effectiveness improves, costs are reduced and stock can be reduced and hence

productivity improves. In addition to the tangible effects. TPM also has intangible effects that are not represented in figures like positive work culture, improved motivation levels, dynamic and enthusiastic work force improved working conditions, clean & safer environment etc. The goal of TPM is to maximize equipment effectiveness or in other words the pursuit of economic LCC (Life Cycle Cost) of equipment physical assets. Industries revolve around man - machine system and TPM aims at maximising the effectiveness of this man-machine system at the minimum LCC. In order to maximise the effectiveness, TPM focuses firstly on "Eliminating Big Losses In Equipment " that interfere with the effective operation of the system.

The Big Losses are:

Down Time Losses	1. Failures: Downtime losses due to unexpected breakdowns 2. Set Up & Adjustment Losses
Speed Losses	3. Idling & Minor Stoppages 4. Reduced Speed
Defect Losses	5. Defects in process 6. Reduced Yield.

Thus, as can be seen above, TPM results in Overall System Effectiveness Overall Equipment Effectiveness (OEE) through the combination of the availability, performance efficiency and the rate of quality products Secondly TPM emphasizes on Periodic Maintenance Preventive Maintenance through Autonomous Maintenance Small Group activities.

5.1 Small Group Activities in TPM

Small group activities in TPM are of the company-led type What gave concrete form to this company led type was the overlapping organization of small groups. In general, small group activities are confined to on-the-floor workers, but in TPM an organization is built that overlaps at several levels of group of executives (TPM Promotion Committee) down to small groups of on-the-floor workers i e an overlapping organization of small groups. The aim is to have the leaders at each level fulfill roles of connection by acting as members of the small group of the level above, thus improving vertical and horizontal communication and unifying the top-down, company-led activities and bottom-up small group activities

When small group activities only involve on-the-floor workers (especially activities of independent type), they often become stereo-typed or lack vitality In the case of TPM, however, all employees from top management down to on-the floor workers participate, each level of the organization is aware of its role and the whole company demonstrates a high level of vitality.

5.2 Autonomous maintenance activities by operators

Autonomous maintenance activities by operators are one of the main features of TPM, and are a key point in its development. Changing the lack of interest in maintenance on the part of operators.

who think that "I'm the operator, and you're the maintenance man"' to developing autonomous maintenance - i e "autonomously maintaining the equipment one uses by oneself" - is not something that can be done overnight that it takes two to three years from when TPM is first introduced to when the introduction stage is completely implemented This is because it takes time to change the attitudes of people.

Under this method, the equipment which one is currently operating is used for on-the-job training, and the operator gradually acquires maintenance knowledge and skills through training and implementation at each step. As he moves up through the steps, he gradually gains a willingness to implement TPM. This consists of the following seven steps.

1. Initial clean-ups
2. Measures against the causes of dust and dirt and places difficult to clean and lubricate
3. Formulation of cleaning and lubrication standards
4. Overall check-up
5. Autonomous check-up
6. Orderliness and tidiness
7. All-out autonomous management

With autonomous maintenance activities through this step method, the workers and equipment improve as the steps are completed. Splendid results are obtained, including the elimination of the six big losses, improved overall equipment effectiveness and the creation of a pleasant workplace.

5.3 Steps in evolving TPM program

The program for developing TPM is divided into twelve steps from the preparatory stage through the stages of commencement and implementation right up until it has been firmly established.

Step 1 : Announcement by the top management of the decision to introduce TPM: The outcome of TPM depends on the top management itself to firmly resolve to introduce TPM and then announcing this intention to all the employees.

Step 2 Education and campaign on the introduction of TPM: Together with carrying out training at each level so that all employees, from the top down to on-the-floor workers, can correctly understand TPM, a campaign through poster slogans and so on is carried out and an atmosphere for commencing TPM is built up.

Step 3. Creation of organizations to promote TPM . Creation of such organizations as a company-wide promotion committee, department promotion committees and special working groups for each theme, and the establishment of a TPM promotion secretariat.

Step 4 : Establishment of basic policies and goals of TPM. Survey of the actual situation of overall equipment effectiveness and the six big losses and the establishment of goals and forecast of expected results.

Step 5 : Formulation of a master plan for evolving TPM: Drawing up a schedule for each of the activities that form the pillars in evolving TPM, from preparations for its introduction up to being assessed. Once these various preparations are completed TPM is "kicked off" - i.e. the commencement of its introduction - in Step 6.

The stages of introducing and implementing TPM (Steps 7-11) are the "five activities that form the pillar in evolving TPM" that were described earlier. "Step 7 : Improvement of the effectiveness of each piece of equipment" and "Step 8 : Formation of an autonomous maintenance setup" are commenced immediately after kick-off. When autonomous maintenance activities first begin, the maintenance department shall be very bust backing up the operation section. According "Step 9 : Creation of a planned maintenance set up in the maintenance department" and "Step 10 : Training to improve operation and maintenance skills" commence at least six months after kick-off. It is effective to commence "Step 11: Creation of a setup for the initial management of equipment" after information has been accumulated on the points of disorder in the reliability and maintainability of equipment currently in operation.

Once TPM is firmly established - i.e. "Step 12 : Perfection in implementation and increased TPM level" - the company continues to challenge ever higher targets.

6.0 SAFETY AND ENVIRONMENT IMPROVEMENT

Maintenance management is nowadays inseparably linked with modern safety and environment improvement techniques Many of the accidents have been correlated to improper operation and maintenance of the plant and equipment. Accident investigation reports have pointed out the necessity to involve plant maintenance functionaries in the initial stages of design and procurement of the equipment and also safety enhancement techniques like Risk identification and assessment An effective safety management and pollution control programme will go a long way in minimising the environmental problems.

7.0 CONCLUSIONS

The combination of judicious use of the maintenance strategies. predictive maintenance techniques. human participation in maintenance like TPM and an effective environment preservation programme have been discussed above as the basis of plant maintenance management It is envisaged that an integrated approach for the implementation of them would lead to greater performance in availability. energy efficiency. safety and environment improvement in sugar industries

Pinch Analysis in Sugar Industry

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PINCH ANALYSIS IN SUGAR INDUSTRY

PROCESS SYSTEMS SERVICES DIVISION
KINETICS TECHNOLOGY INDIA LIMITED
NEW DELHI

TRAINING PROGRAMME ON
ENERGY EFFICIENCY AND ENVIRONMENT IMPROVEMENT IN SUGAR INDUSTRY
25 - 26 MARCH 1998

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PRESENTATION OVERVIEW

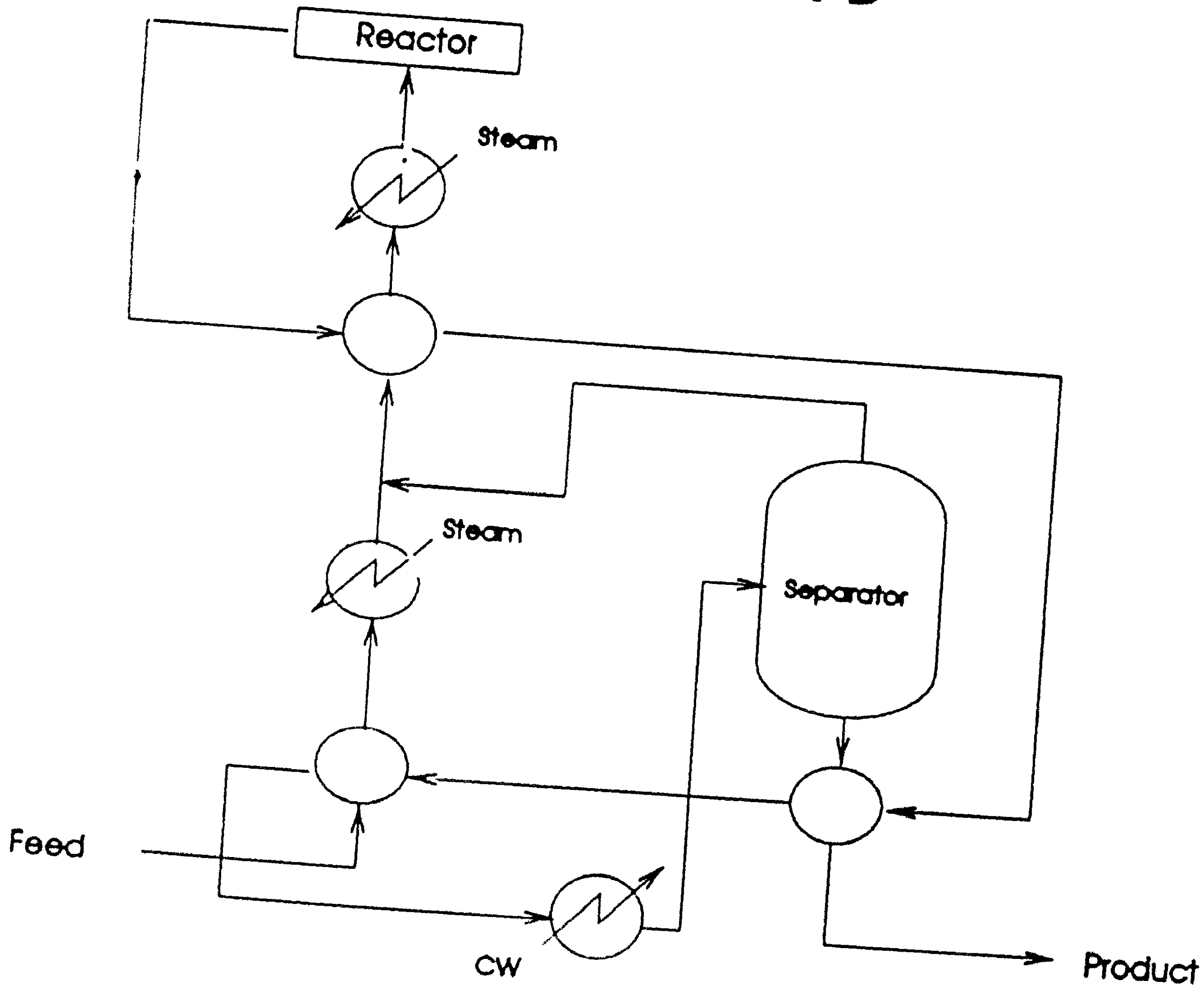
- INTRODUCTION TO PINCH TECHNOLOGY
- PLACEMENT OF HEAT ENGINES, EVAPORATORS, ETC.
- APPLICATION TO SUGAR INDUSTRY

INTRODUCTION TO PINCH TECHNOLOGY

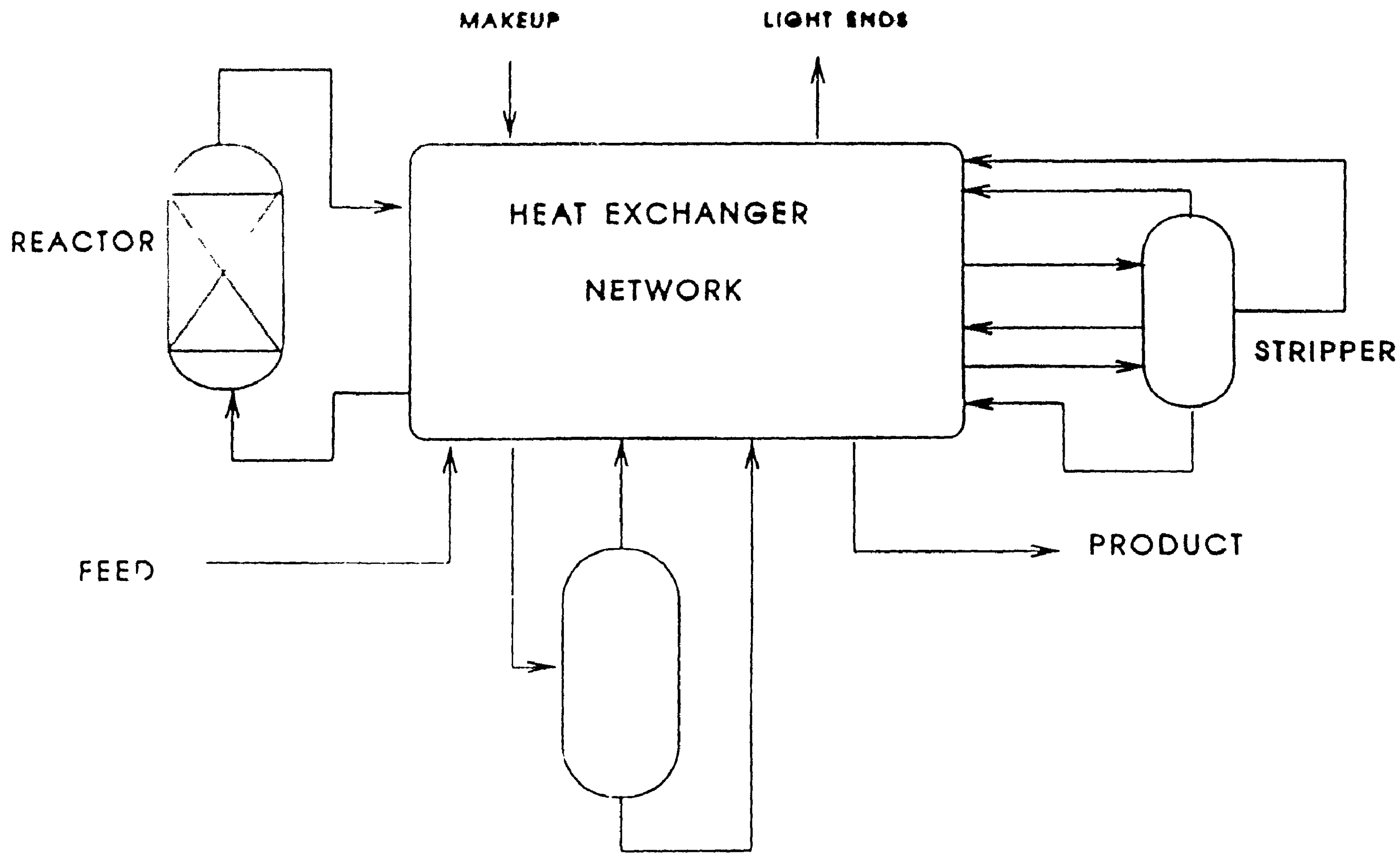
PINCH TECHNOLOGY TOOLS

- COMPOSITE CURVES
- GRAND COMPOSITE CURVES
- AREA vs ENERGY PLOT

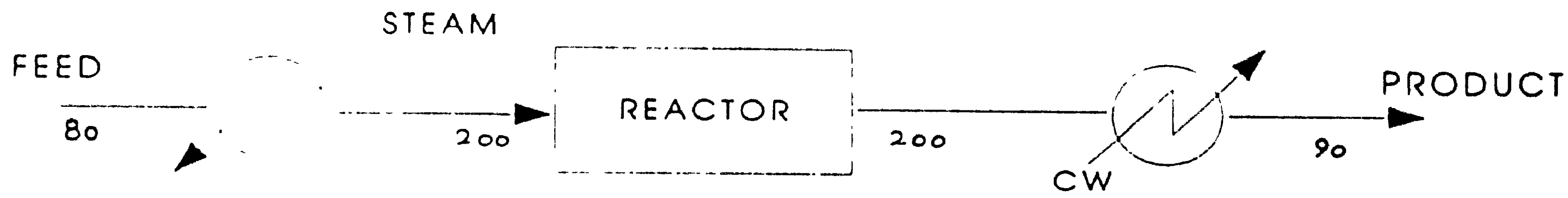
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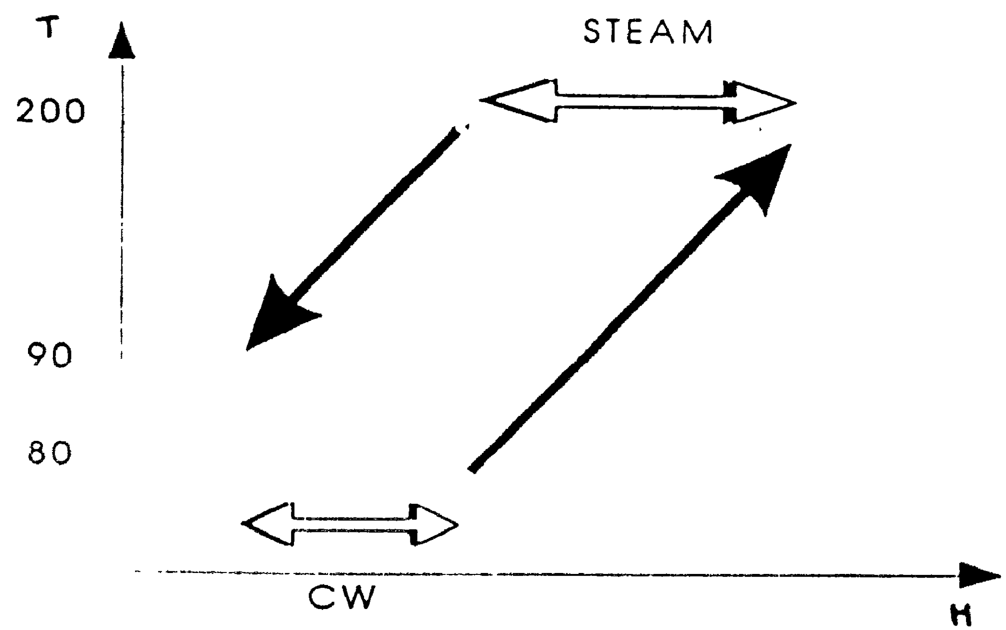


GENERAL PROCESS PLANT

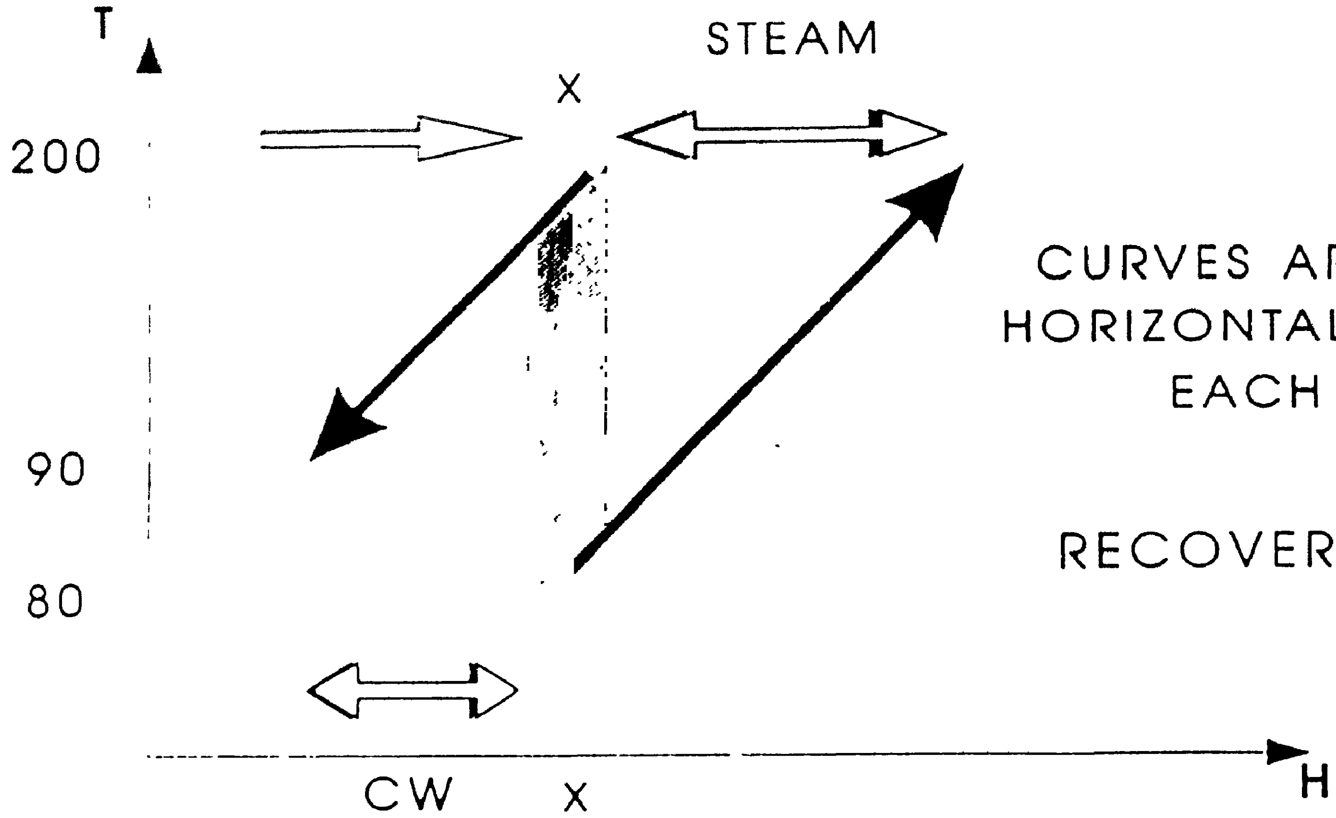


CONSIDER THIS SIMPLE PROCESS ...





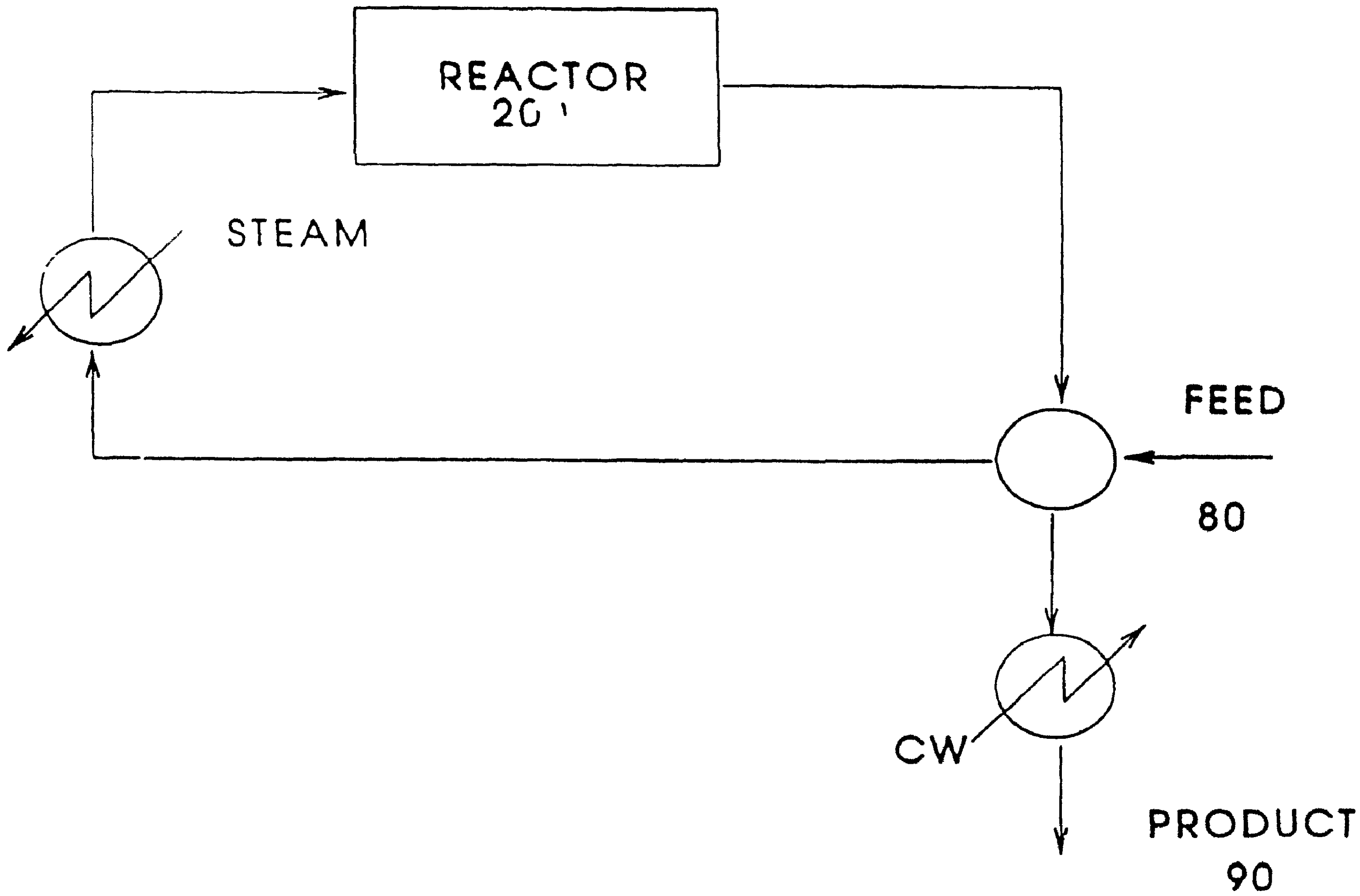
PROCESS HEAT EXCHANGE REDUCES BOTH STEAM AND COOLING WATER



CURVES ARE 'SHIFTED' HORIZONTALLY TOWARDS EACH OTHER

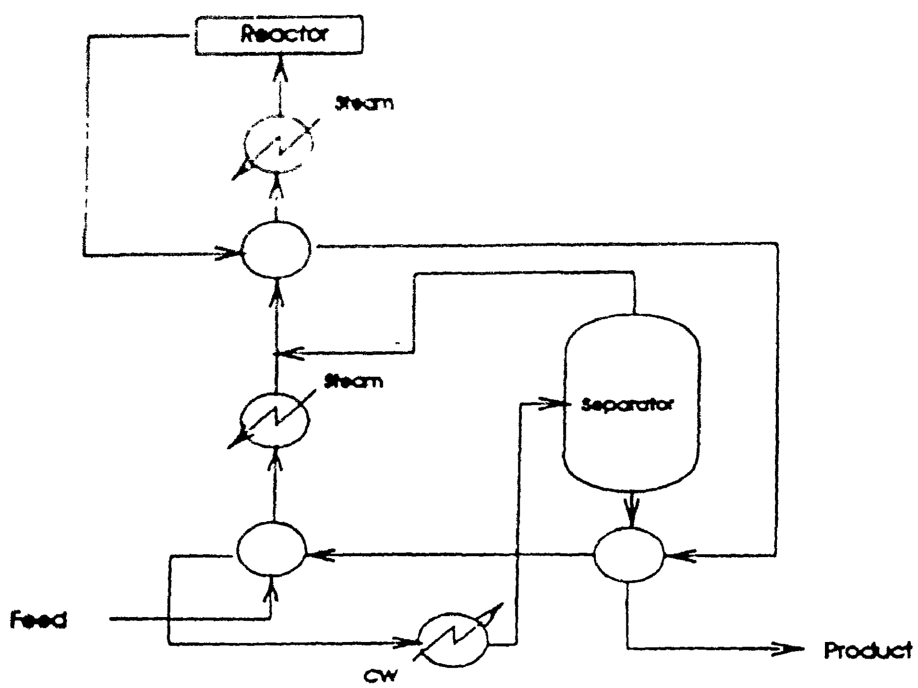
RECOVERED HEAT = X

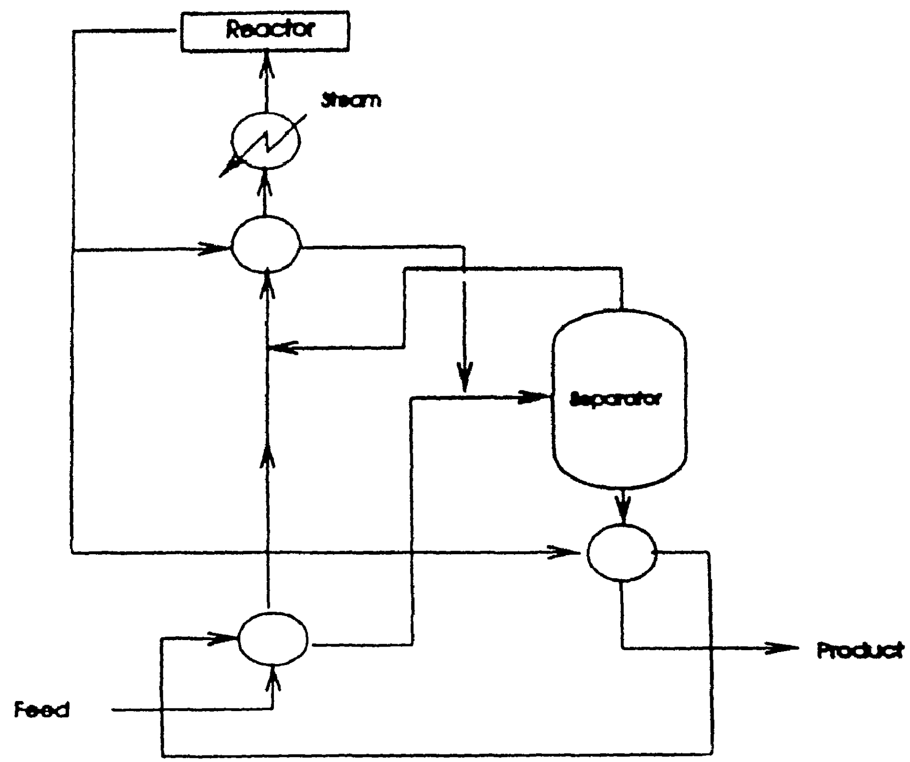
IMPROVED DESIGN ...



KTI

DESIGN COMPARISON FOR SIMPLE PROCESS

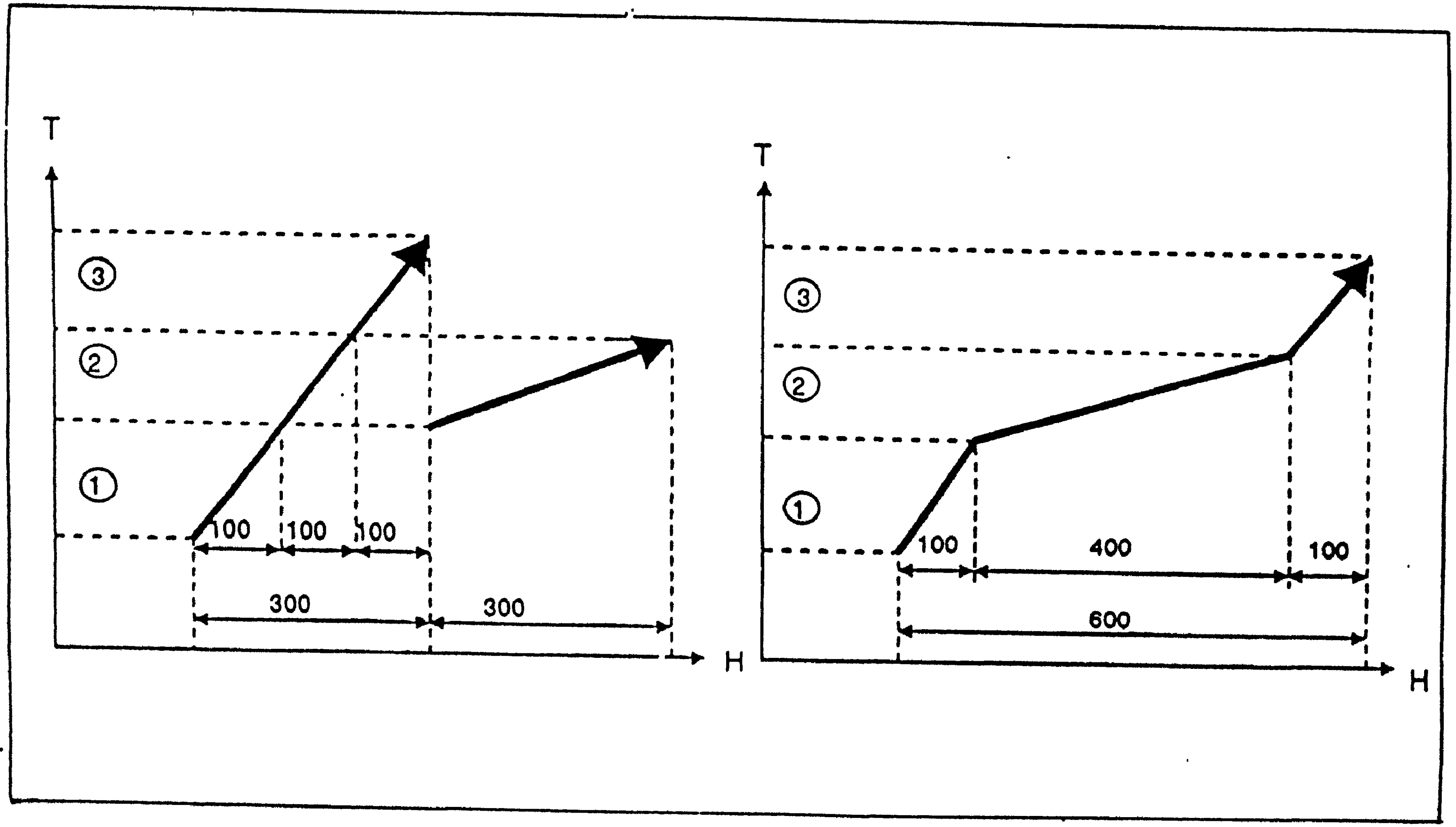


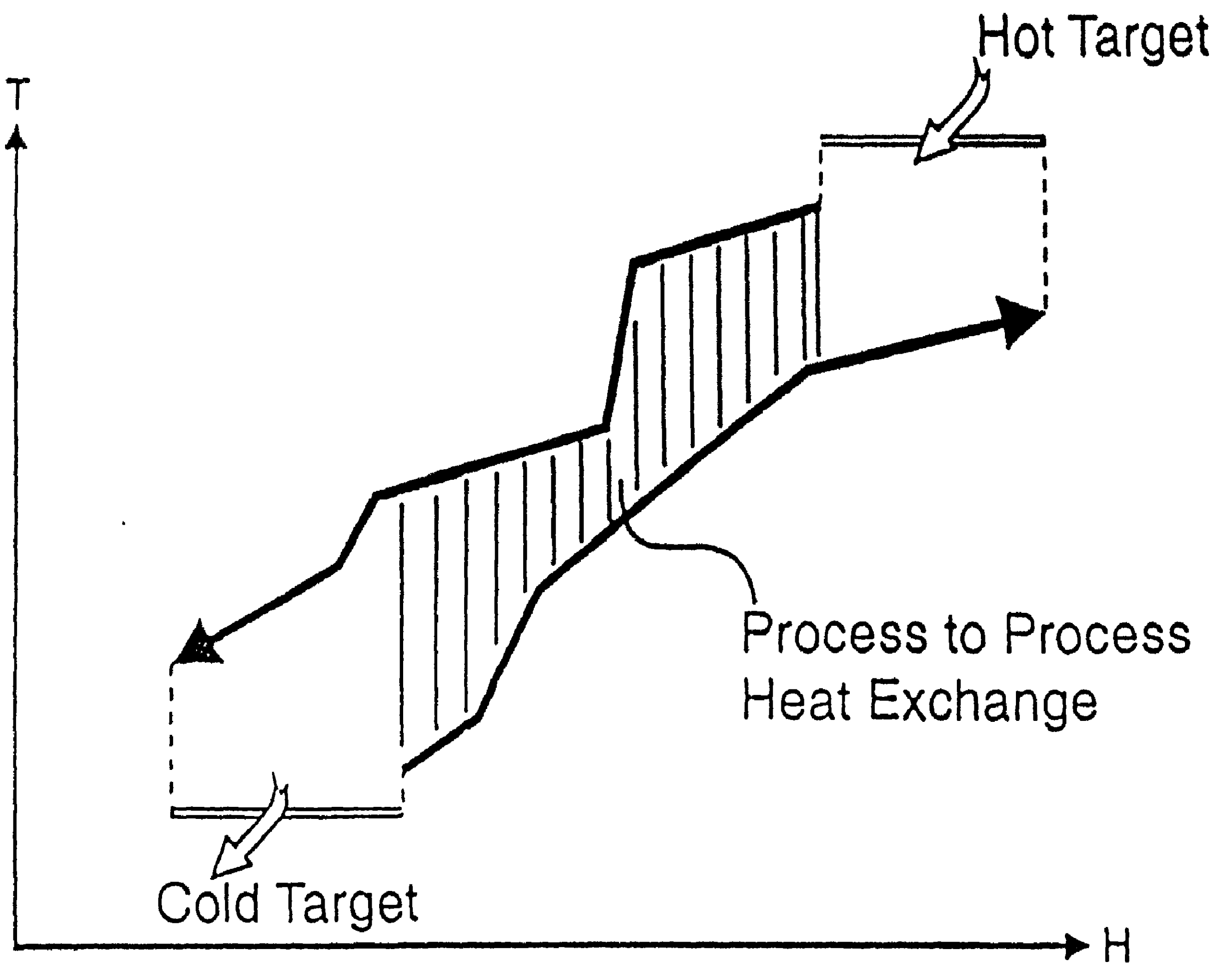


STEAM	=	1722
CW	=	654
AREA	=	629

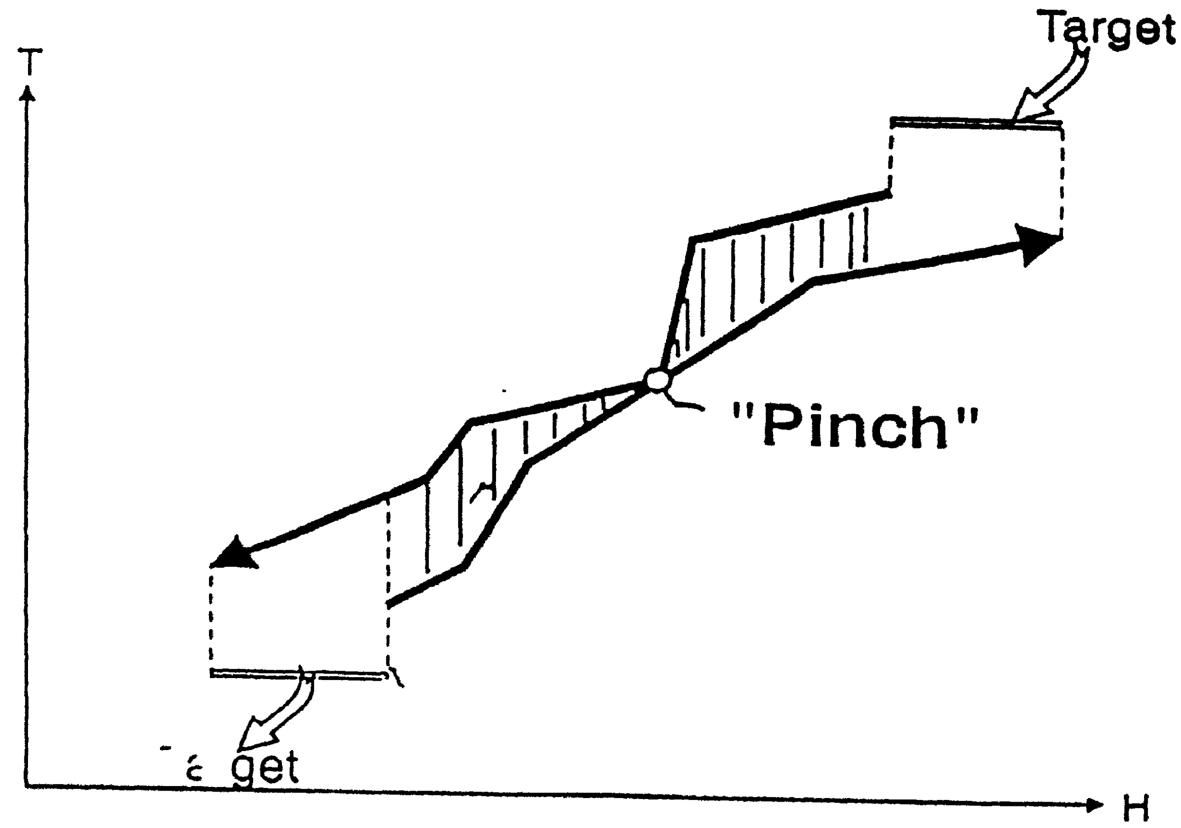
STEAM	=	1068
CW	=	0
AREA	=	533

THE CONCEPT OF COMPOSITE CURVE

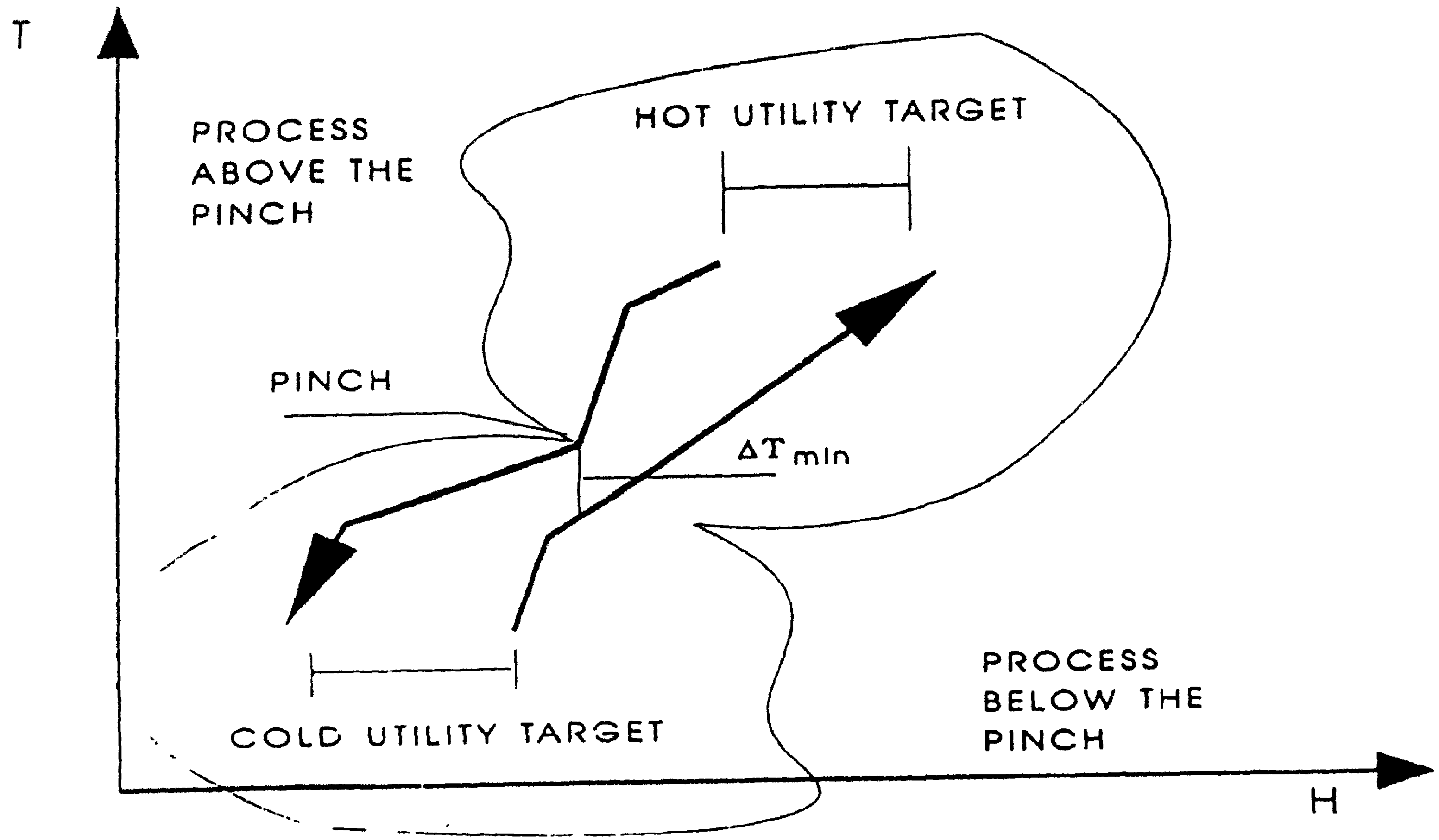




Hot and Cold Composite Curves

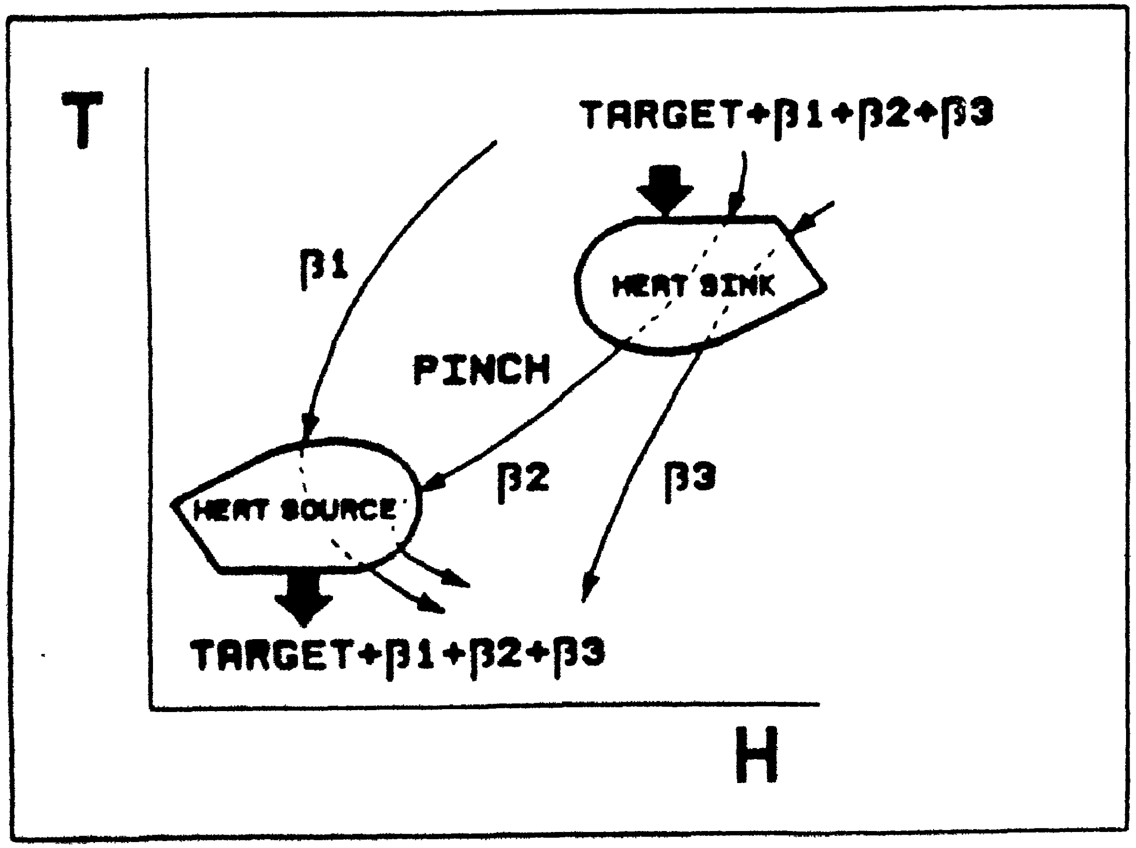


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THREE IMPORTANT RULES FOR DESIGN:

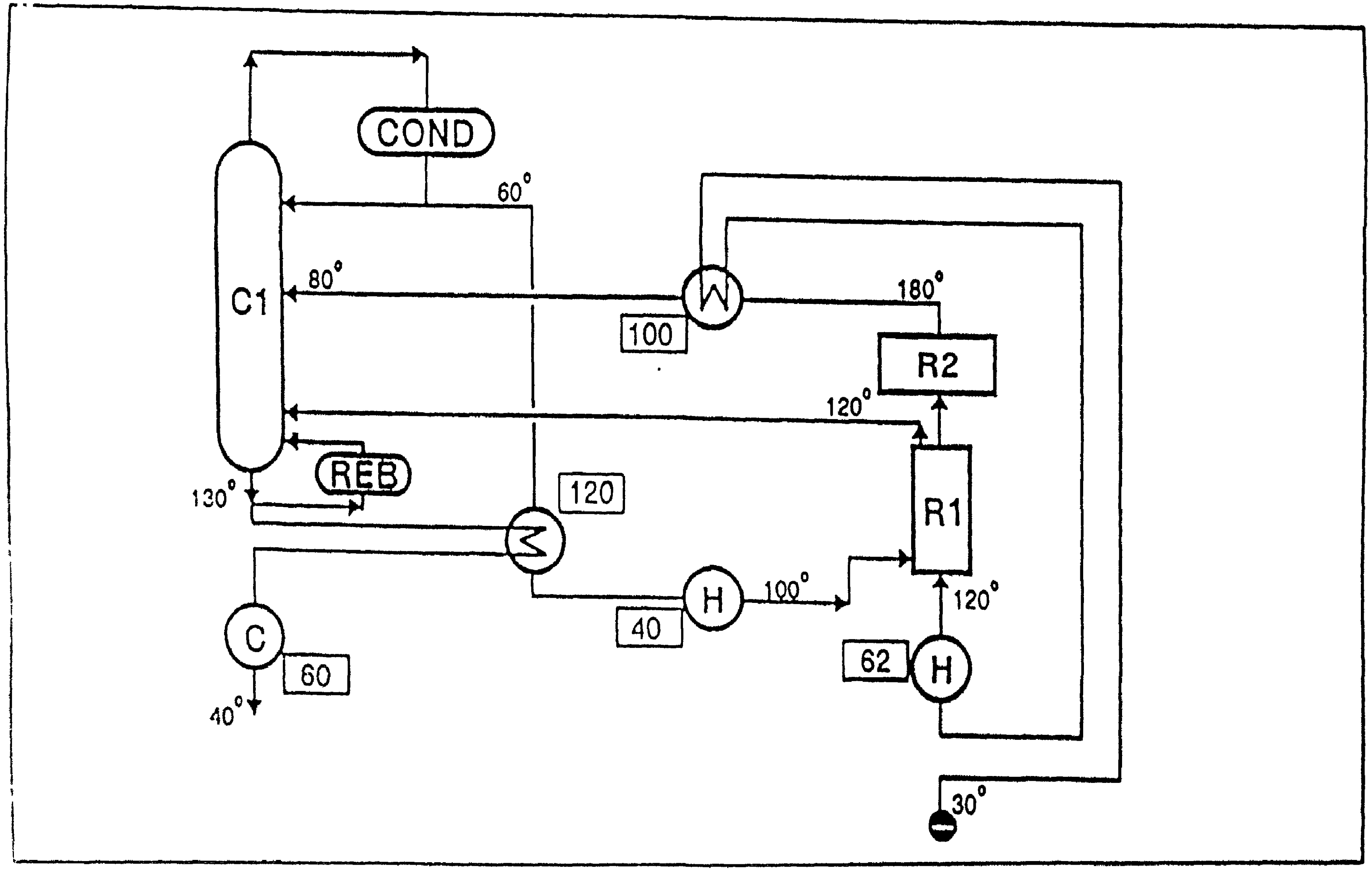


- NO PROCESS HEAT ACROSS ($\beta 2=0$)
- NO COLD UTILITY ABOVE ($\beta 3=0$)
- NO HOT UTILITY BELOW ($\beta 1=0$)

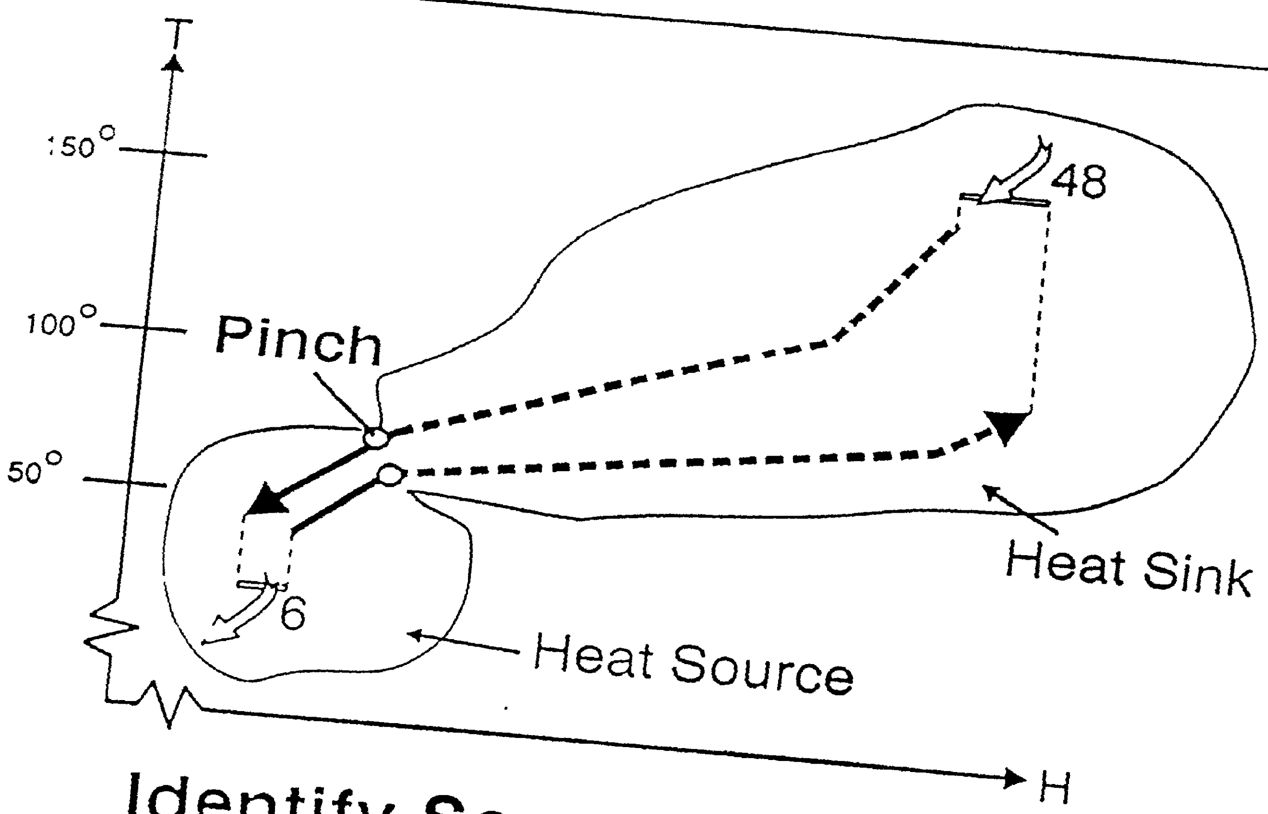
EXAMPLE OF APPLICATION

KTI

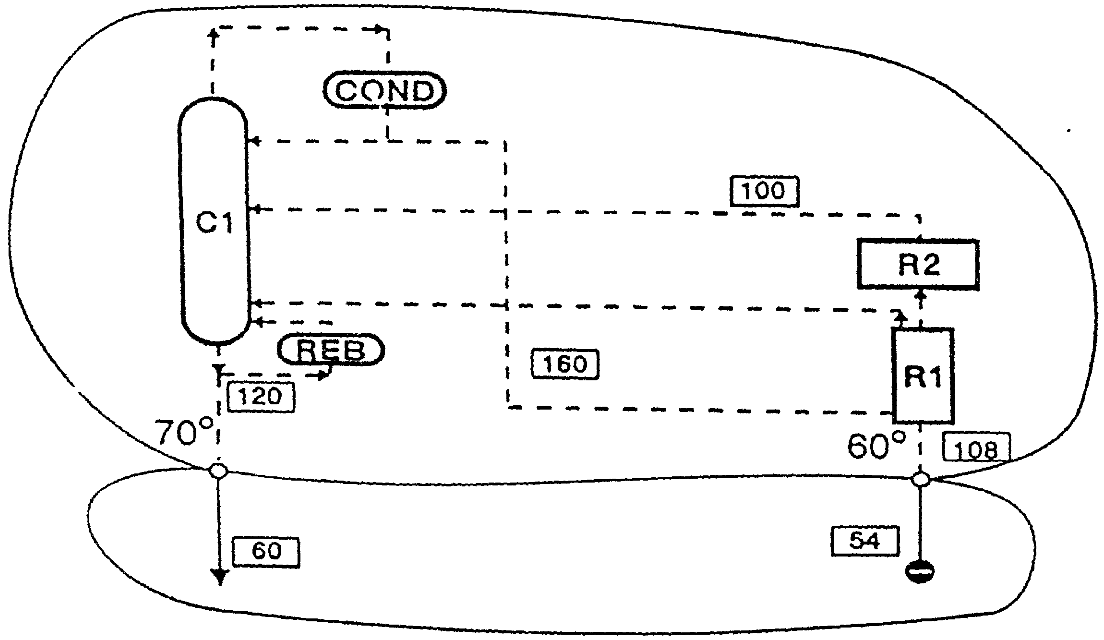
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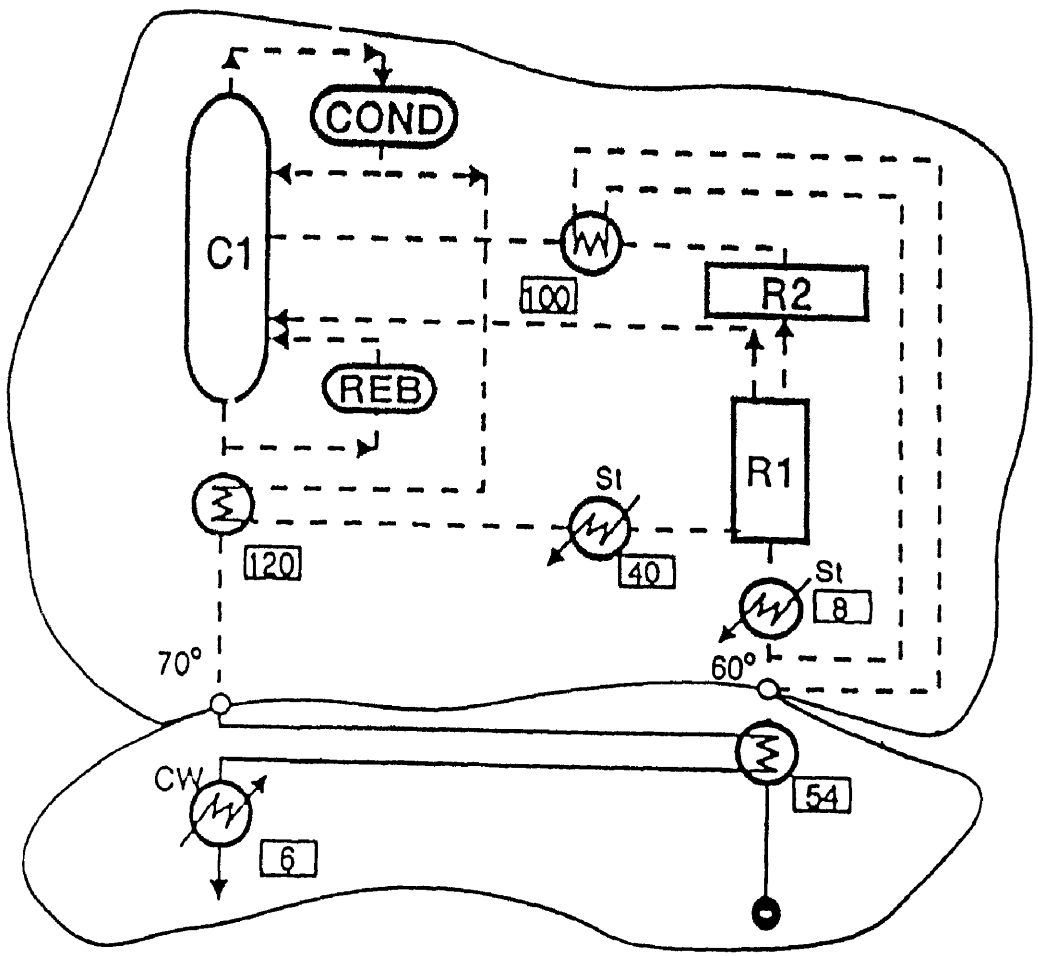
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Identify Source and Sink

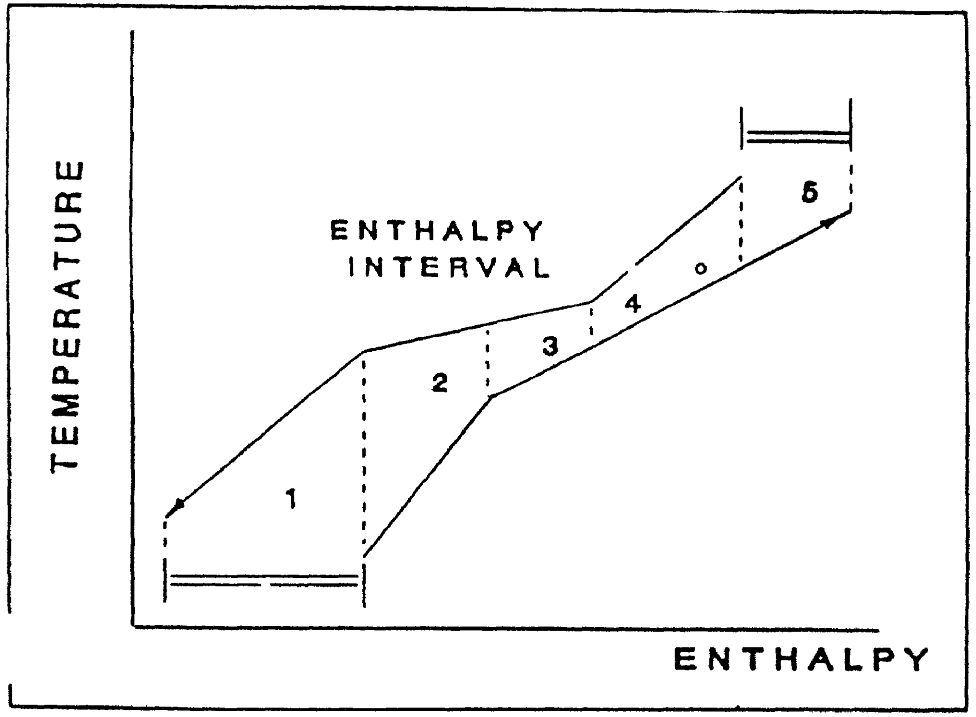


Divide at the Pinch



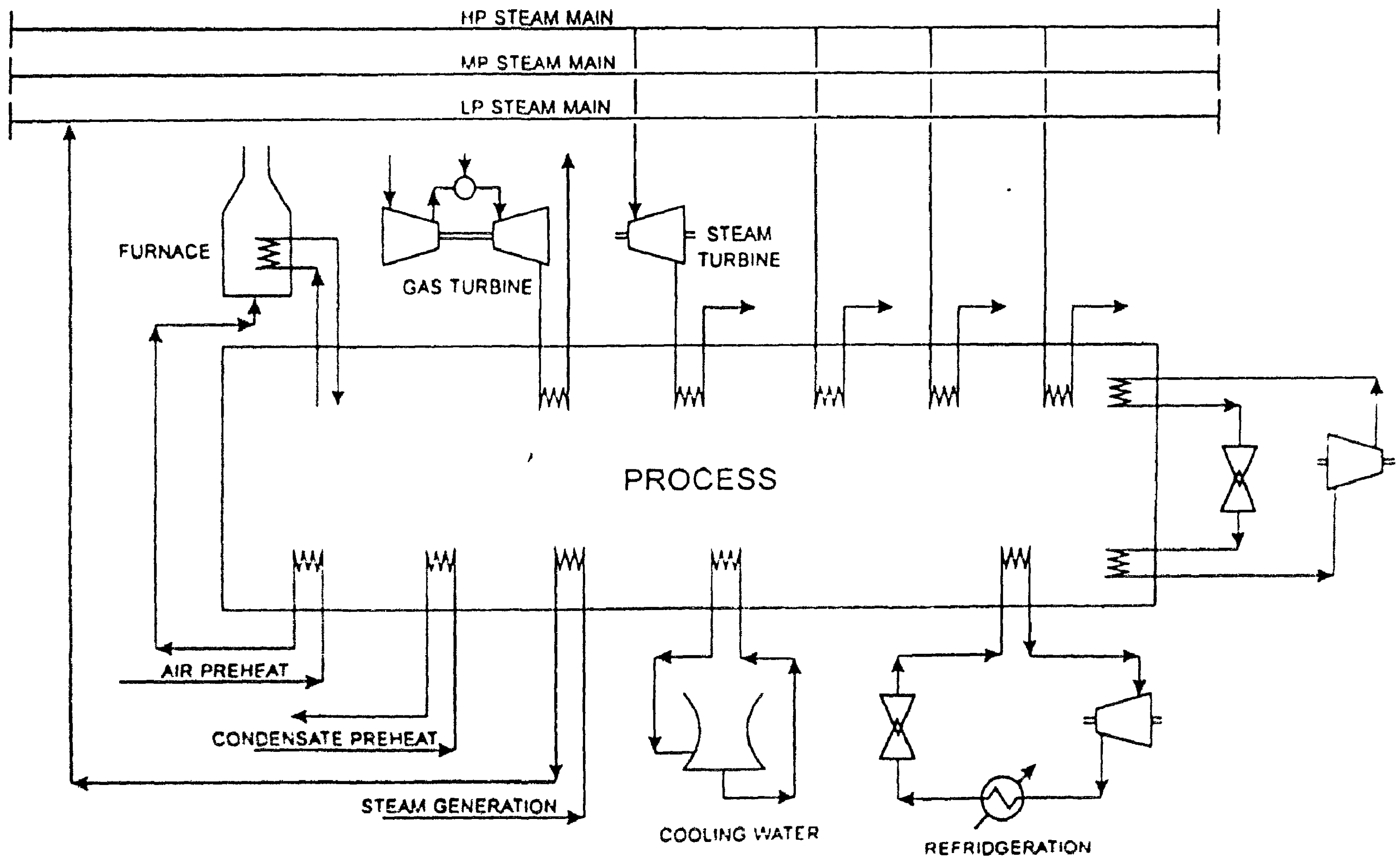
Design in Two parts ⟹ Targets Achieved

COMPOSITE CURVES... AREA TARGET



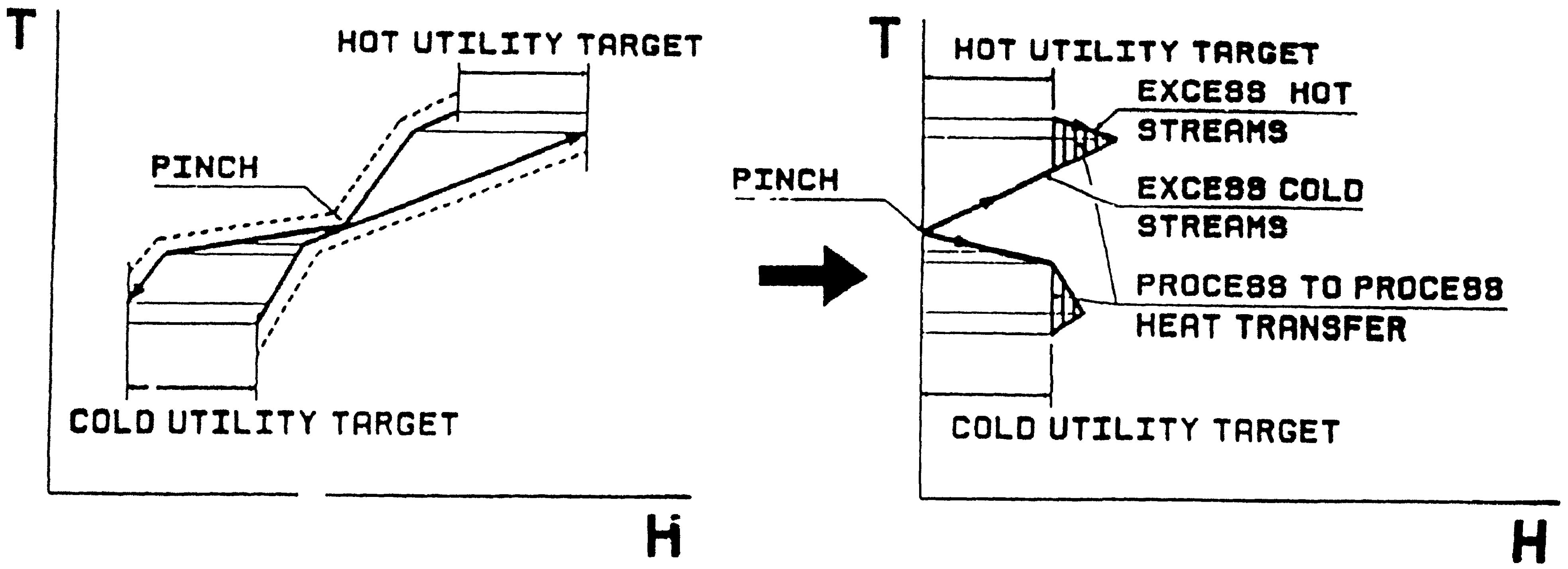
$$A_{min} = \sum_{interval} \frac{1}{\Delta T_{LM}} \sum_{j\ streams} \left(\frac{q_j}{h_j} \right)$$

This is fine for simple utilities but we can have a range of utilities to choose from.

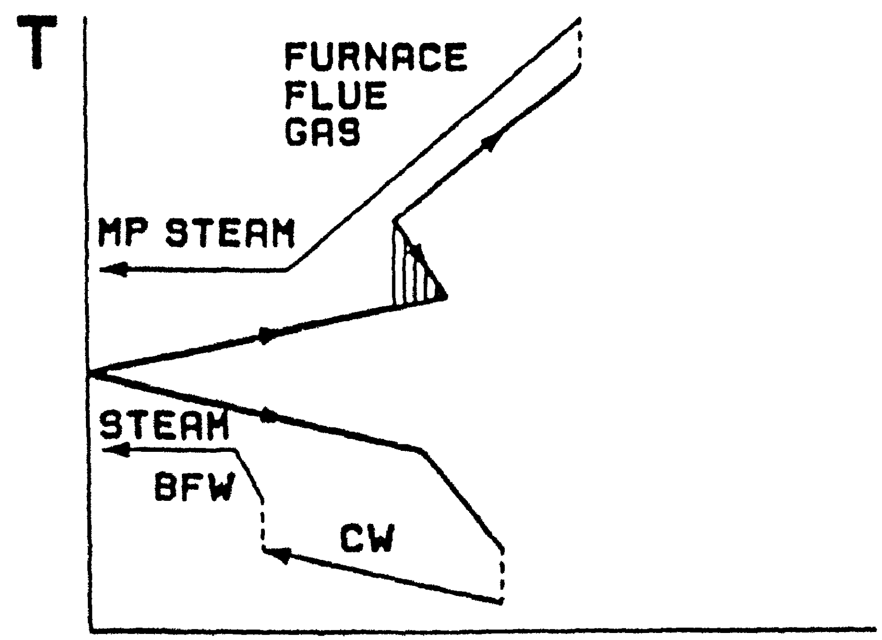


Choice of utilities to service the process

GRAND COMPOSITE CURVE

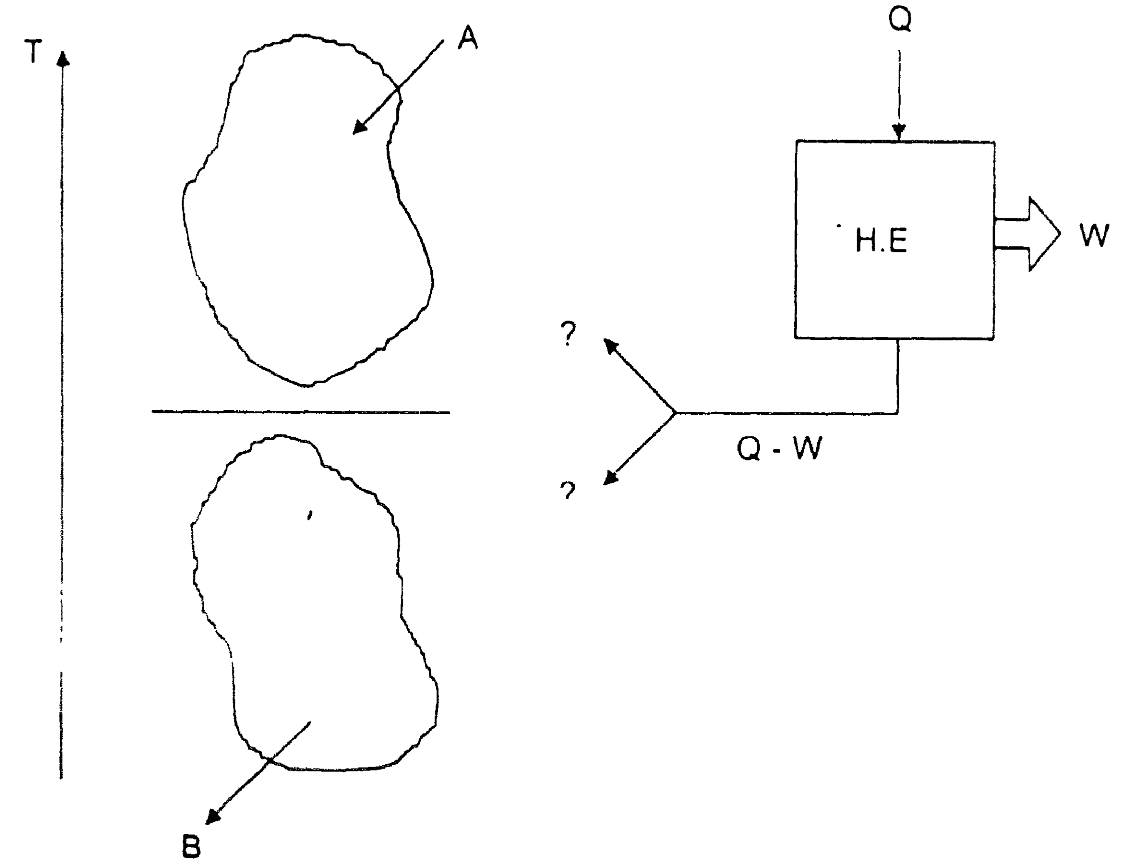


USE OF GRAND COMPOSITE CURVE



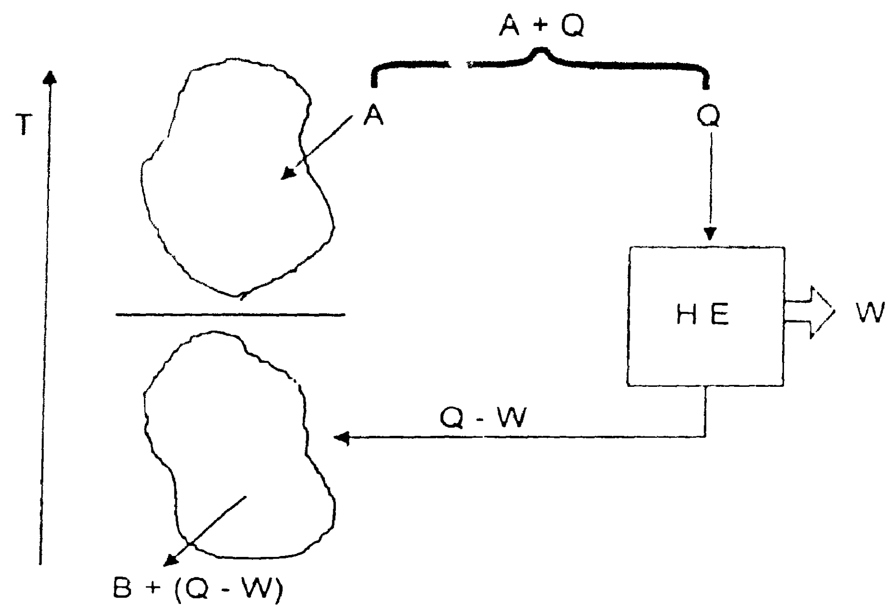
WE CAN SELECT APPROPIATE UTILITY LEVELS

COMBINED HEAT AND POWER



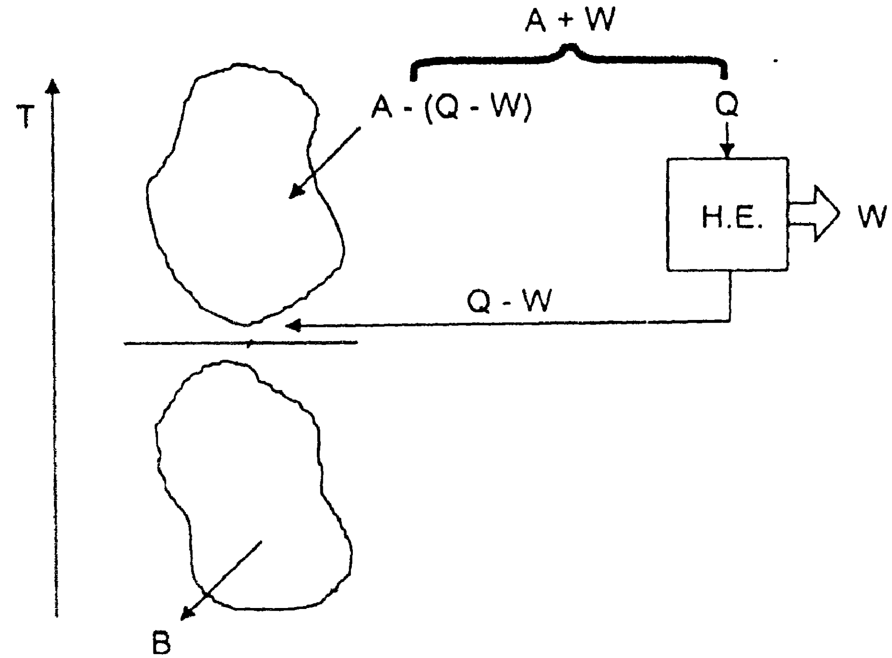
How should we integrate a heat engine ?

If you integrate across the pinch,



you waste capital and energy

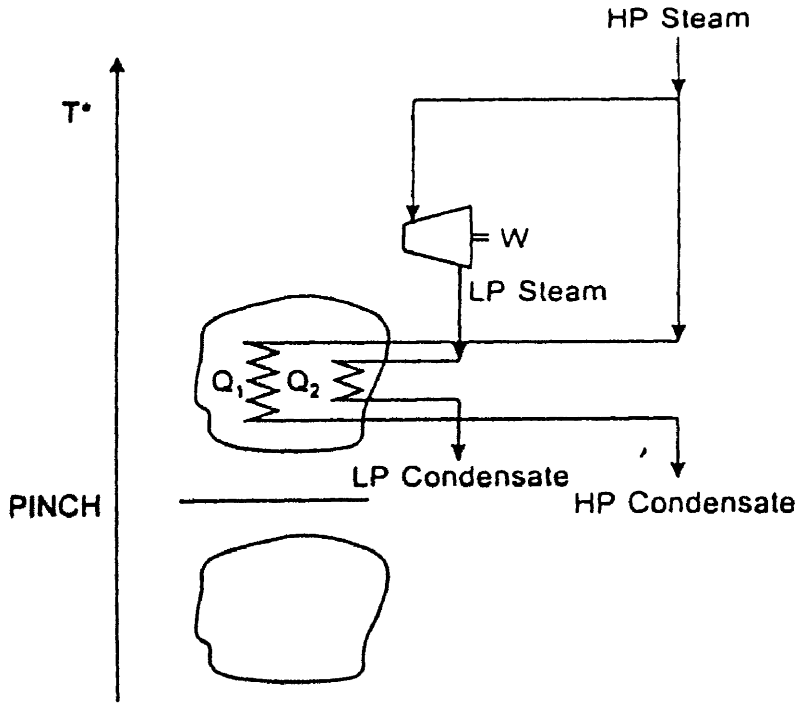
Integrate above the pinch.

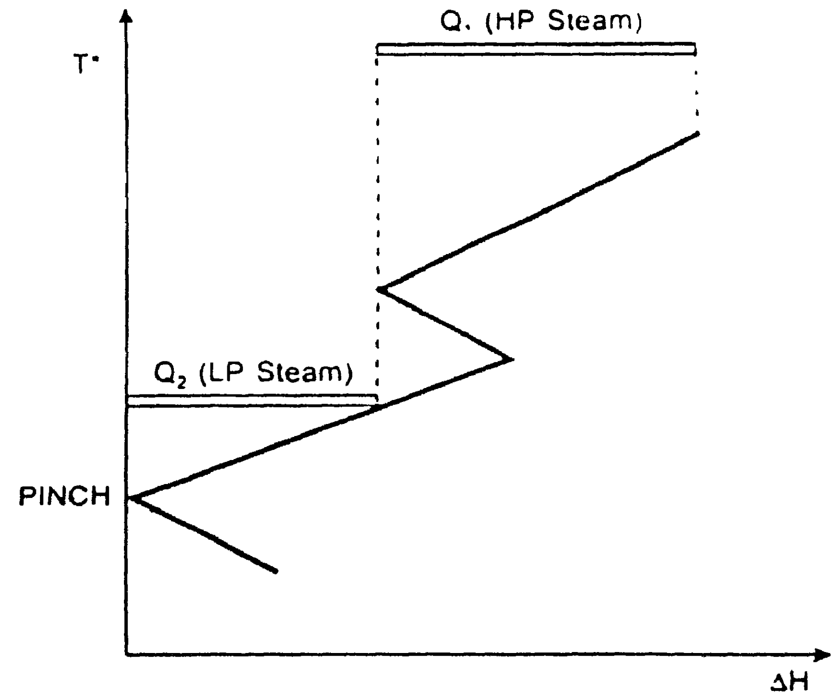


100% conversion
Heat ⇒ Work

Appropriate placement of
heat engines :

NOT ACROSS THE PINCH





The Grand Composite Curve can be used to size steam turbine cycles

PINCH TECHNOLOGY : APPLICATIONS IN ...

- REFINERY
- PETROCHEMICALS
- FERTILIZERS
- SPECIALITY CHEMICALS
- BREWERY
- FOOD PROCESSING
- PULP AND PAPER
- CEMENT
- TEXTILES
- SUGAR

APPLICATION OF PINCH ANALYSIS IN SUGAR INDUSTRY

KTI

A MANNESMANN COMPANY

INTRODUCTION

- SUGAR INDUSTRY IS A LARGE CONSUMER OF ENERGY

- FORMS OF ENERGY

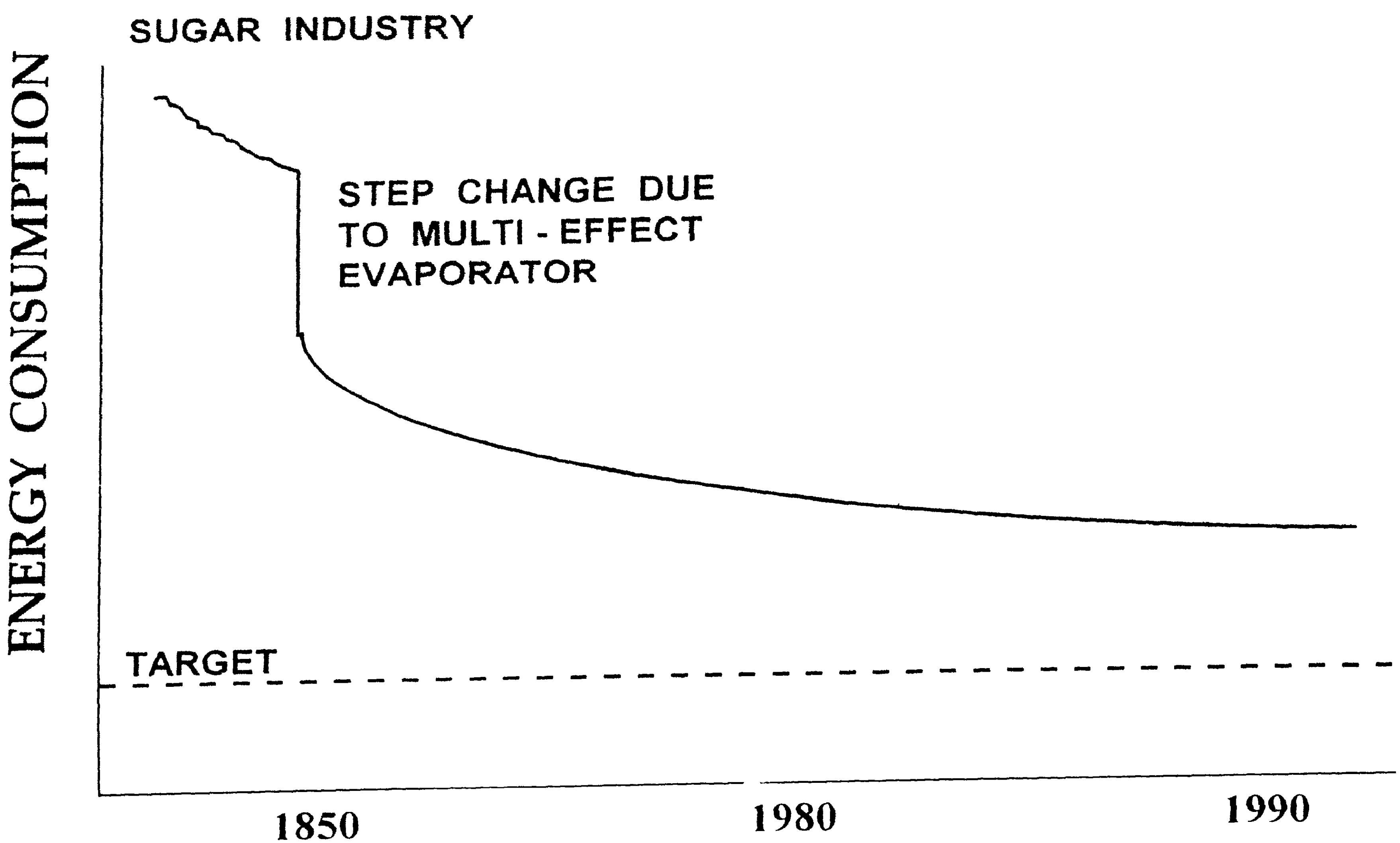
POWER	:	15 - 25 KWH / T of Cane
STEAM	:	0.35 - 0.5 T / T of Cane

- POWER REQUIRED FOR
  - MECHANICAL CRUSHING
  - PUMP DRIVES
  - CENTRIFUGATION

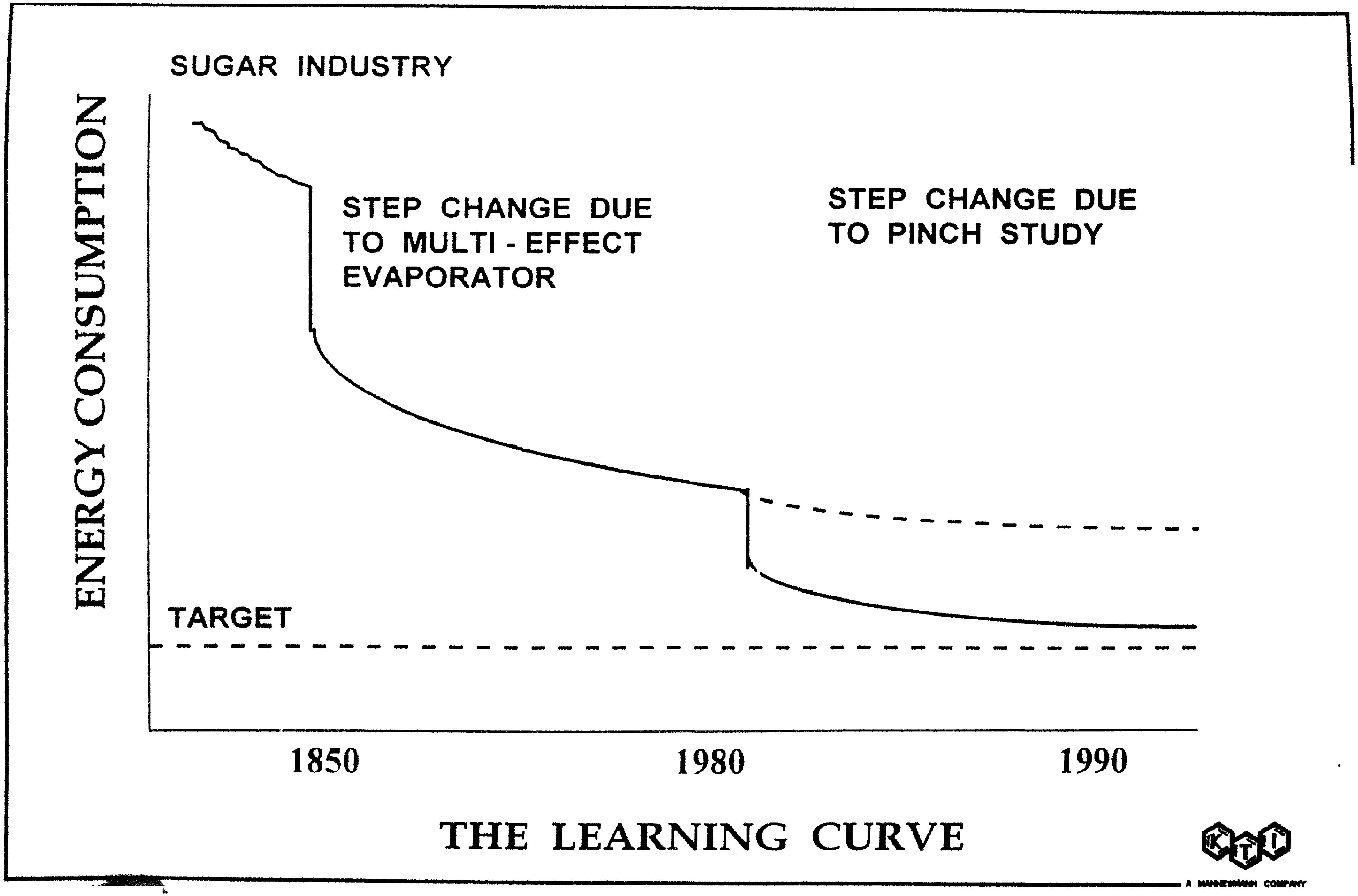
- STEAM REQUIRED FOR
  - EVAPORATION
  - PAN DRYING

BACKGROUND

- SUGAR INDUSTRY HAS BEEN IN EXISTENCE FOR OVER TWO CENTURIES
- COMPARITIVELY QUITE MATURE AS COMPARED TO OTHER PROCESS INDUSTRIES
- CREDITED WITH SEVERAL INNOVATIONS
- PROVIDED FIRST EXAMPLES OF PROCESS INTEGRATION
  - DOUBLE EFFECT EVAPORATION, RILLIEUX (1843)
  - USE OF ENGINE EXHAUST STEAM TO DRIVE EVAPORATORS (1868)
- SUGAR INDUSTRY IS THUS WELL HEAT INTEGRATED COMPARED TO OTHER YOUNGER INDUSTRIES
- HOWEVER, PINCH ANALYSIS IDENTIFIES FURTHER POTENTIAL FOR ENERGY SAVINGS



THE LEARNING CURVE



THE LEARNING CURVE

SUGAR MANUFACTURE

BROADLY DIVIDED INTO TWO SECTIONS

- MANUFACTURE OF RAW SUGAR
  - FROM SUGAR CANE
  - FROM SUGAR BEET

- REFINING OF RAW SUGAR

STEPS FOR PINCH ANALYSIS IN SUGAR INDUSTRY

1. TARGETTING
   - ANALYSIS OF COMPOSITE CURVES
   - COMPARISON OF EXISTING CONSUMPTION WITH TARGETS
   - SCOPE FOR ENERGY SAVINGS

2. PROCESS MODIFICATIONS
   - IDENTIFY CHANGES TO OPERATING CONDITIONS, TEMPERATURES, PRESSURES FOR IMPROVING TARGETS

STEPS FOR PINCH ANALYSIS IN SUGAR INDUSTRY

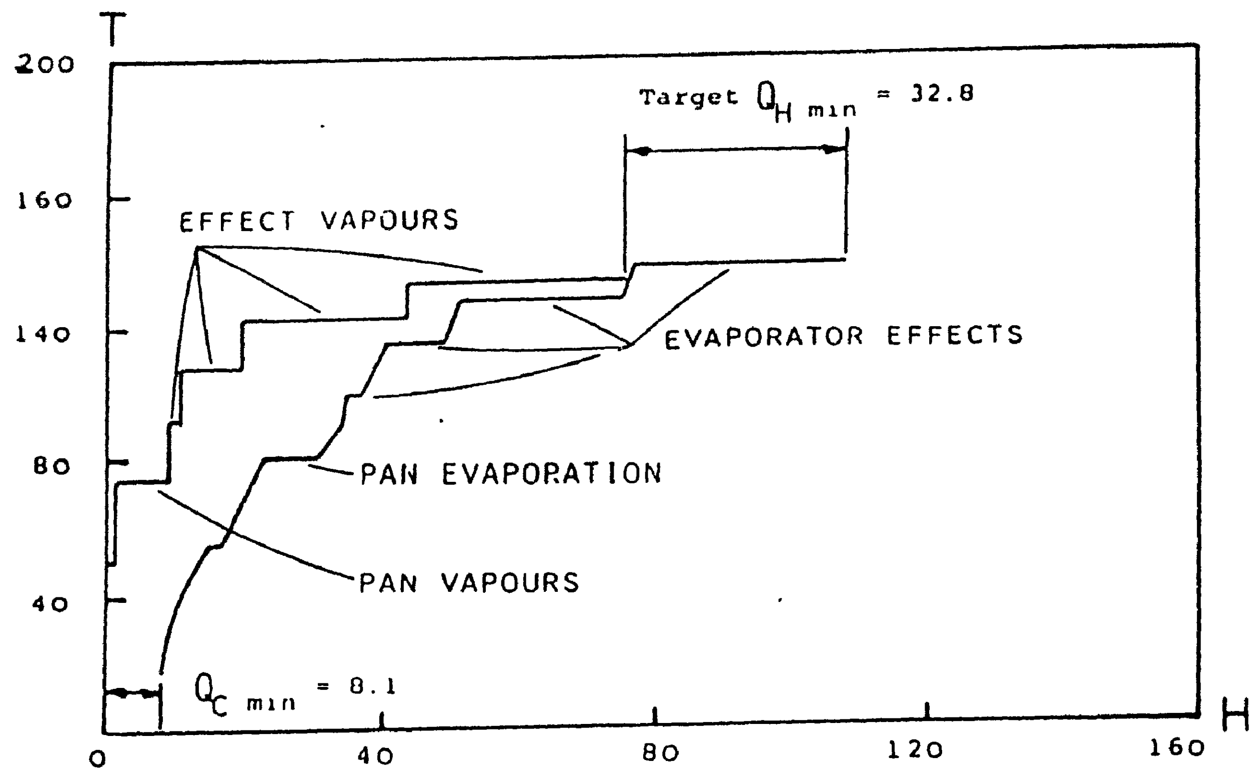
3. EXAMINE COMBINED HEAT AND POWER
   - ANALYSIS OF GRAND COMPOSITE CURVES
   - MOST APPROPRIATE CONFIGURATION
   - SCOPE FOR SAVINGS

4. DESIGN OF HEAT RECOVERY NETWORKS
   - COST BENEFIT SAVINGS
   - PRIORITISE PROJECTS FOR IMPLEMENTATION

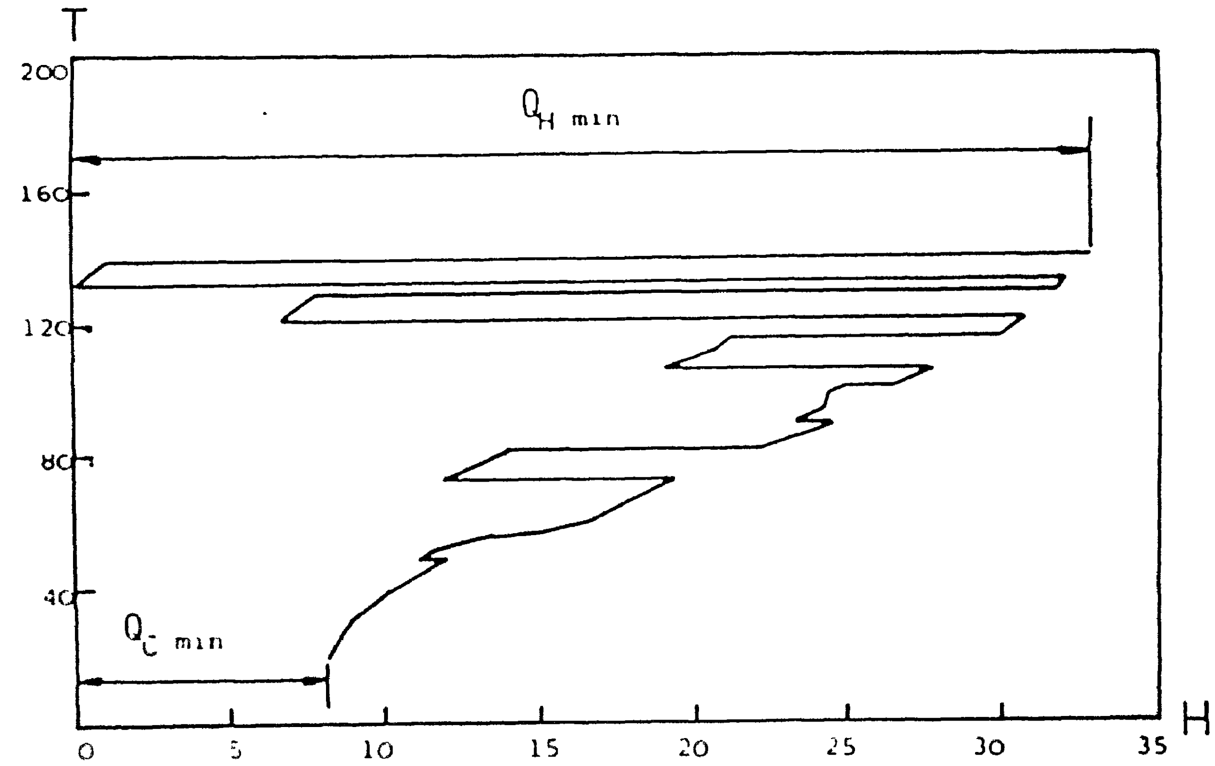
File Edit Options Update Help

60 Find:

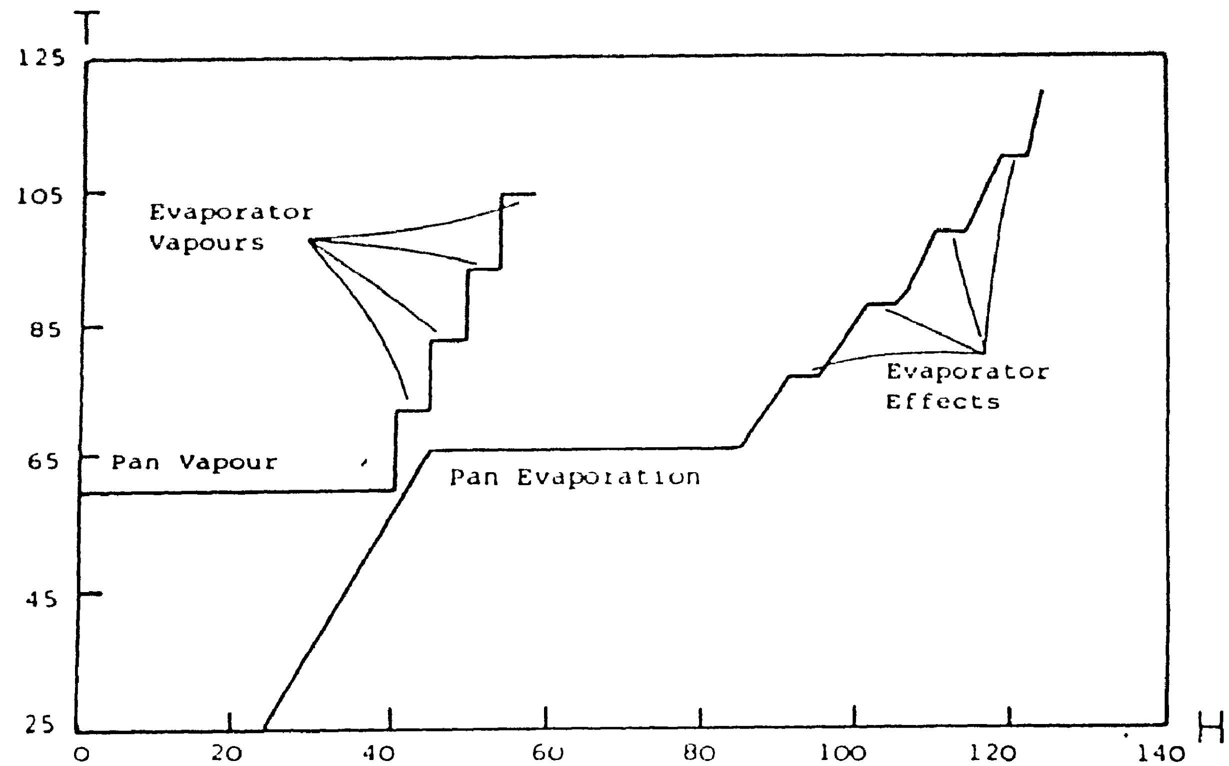
No	Type	Name	TS	TT	dH	MCP
			C	C	kW	kW/K
1	Cold	Calorizators Water	50.00	60.00	2.100000	.210
2	Cold	Calorizators Beets	30.00	60.00	2.200000	7.333E-2
3	Cold	Raw Juice Heater	60.00	85.00	2.900000	.116
4	Cold	2nd Carb Heater	80.00	92.00	1.700000	.142
5	Cold	2nd Filter Heater	89.00	92.00	4.000E-1	.133
6	Cold	Thin Juice Boiler	98.00	111.00	1.800000	.138
7	Cold	Thin Juice Heater	96.00	126.00	4.200000	.140
8	Cold	Waste Heater	18.00	90.00	4.900000	6.806E-2
9	Cold	Sacch Milk Heater	40.00	85.00	1.700000	3.778E-2
10	Cold	H&L Melter	35.00	95.00	1.600000	2.667E-2
11	Cold	1st Effect Duty	137.00	138.00	33.[illegible]	33.500
12	Hot	1st Effect Vapor	134.00	133.00	32.[illegible]	32.100
13	Cold	2nd Effect Duty	127.00	128.00	23.[illegible]	23.900
14	Hot	2nd Effect Vapor	123.00	122.00	24.[illegible]	24.000
15	Cold	3rd Effect Duty	114.00	115.00	8.800000	8.800
16	Hot	3rd Effect Vapor	108.00	107.00	8.900000	8.900
17	Cold	4th Effect Duty	99.00	100.00	1.400000	1.400
18	Hot	4th Effect Vapor	92.00	91.00	1.400000	1.400
19	Cold	White, interpans	80.00	81.00	7.900000	7.900
20	Hot	Pan Vapor 1	75.00	74.00	7.900000	7.900
21	Cold	Raw Pan	55.00	56.00	1.100000	1.100
22	Hot	Pan Vapor 2	51.00	50.00	1.100000	1.100



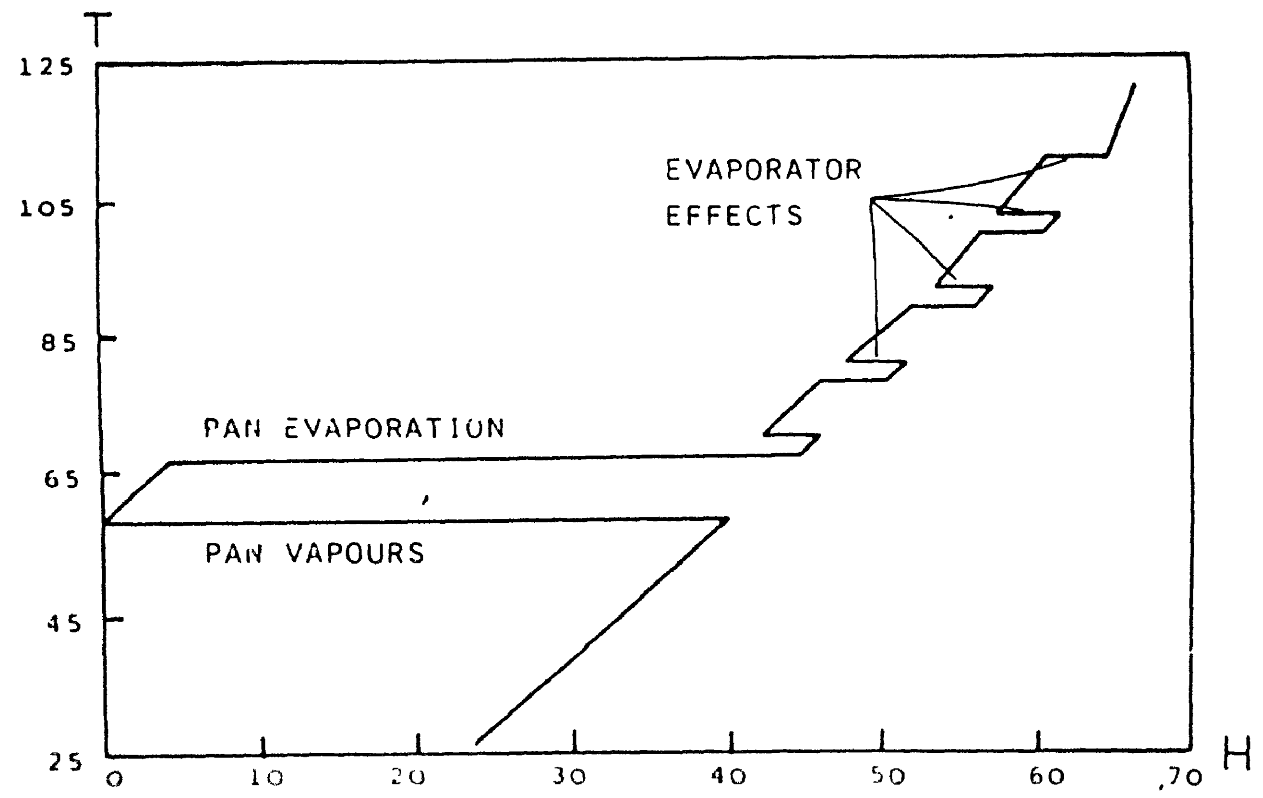
COMPOSITE CURVES FOR BEET SUGAR FACTORY



GRAND COMPOSITE CURVE FOR BEET SUGAR FACTORY



COMPOSITE CURVES FOR CANE SUGAR FACTORY



GRAND COMPOSITE CURVE FOR CANE SUGAR FACTORY

OBSERVATIONS

BEET FACTORY

- FOUR EFFECT EVAPORATOR USED
- CONSIDERABLE VAPOR BLEED FROM FIRST THREE EFFECTS, CAN BE USED FOR JUICE HEATING
- SIGNIFICANT EVAPORATION DUTY - 70 %
- PINCH CAUSED BY FIRST EVAPORATOR DUTY / VAPOR AT 135 °C
- PAN VAPOR CONDENSED BY COOLING WATER

OBSERVATIONS (Contd.)

CANE FACTORY

- COMPOSITE CURVES SIMILAR IN SHAPE
- EVAPORATION DUTY CONSIDERABLY SMALLER
- PINCH CAUSED BY PAN VAPOR AT 60 °C
- PAN EVAPORATION CAN BE CARRIED OUT BY STEAM
- PART OF THE PAN VAPOR CAN BE CONDENSED BY COOLING WATER

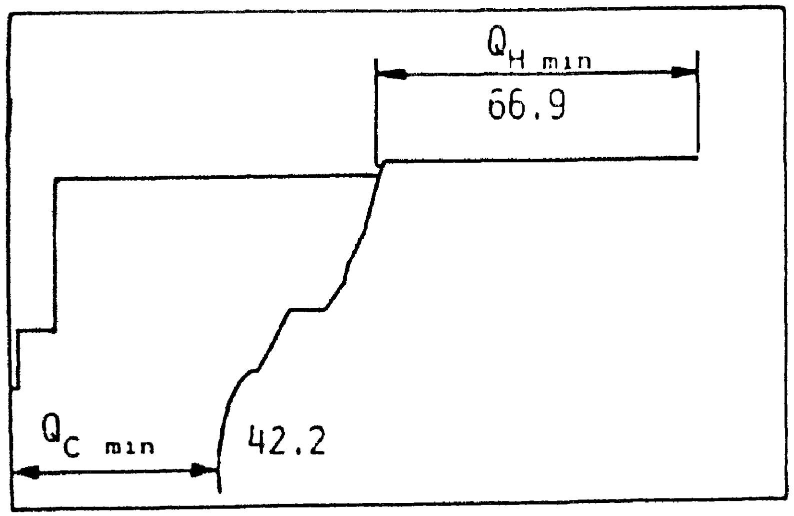
BASIC ASSUMPTION IN ABOVE IS FOUR EFFECT EVAPORATION

MULTIPLE EFFECT EVAPORATION

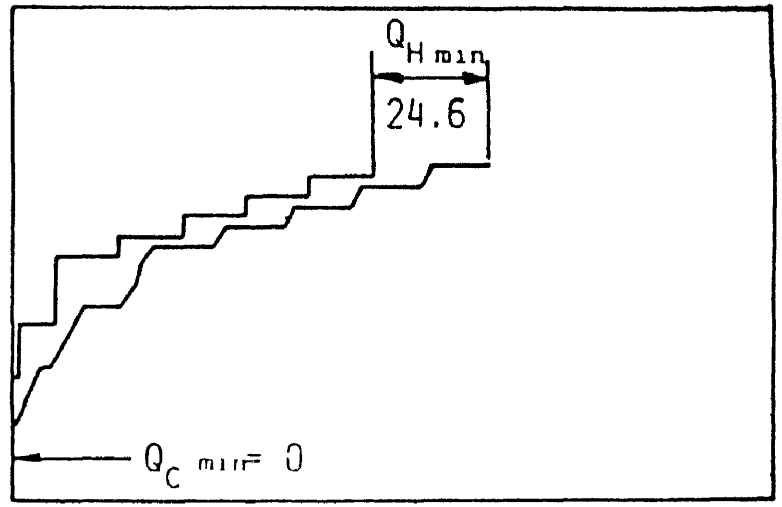
- INCREASE IN NUMBER OF EFFECTS LEADS TO :

1. REDUCTION IN BOTH HOT AND COLD UTILITIES
2. REDUCTION IN PINCH TEMPERATURE, BETTER HEAT INTEGRATION
3. INCREASE IN CAPITAL

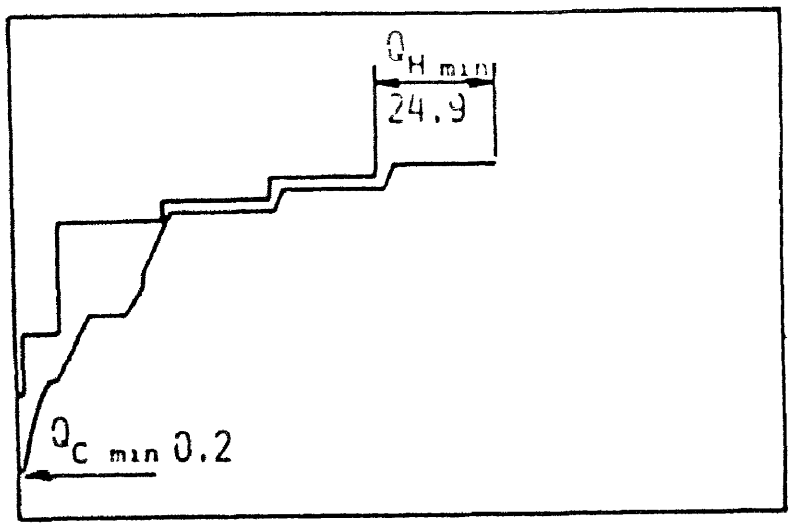
COMPOSITE CURVES FOR MULTIPLE EFFECT EVAPORATION



A) SINGLE EFFECT EVAPORATION



C) FIVE EFFECT EVAPORATION

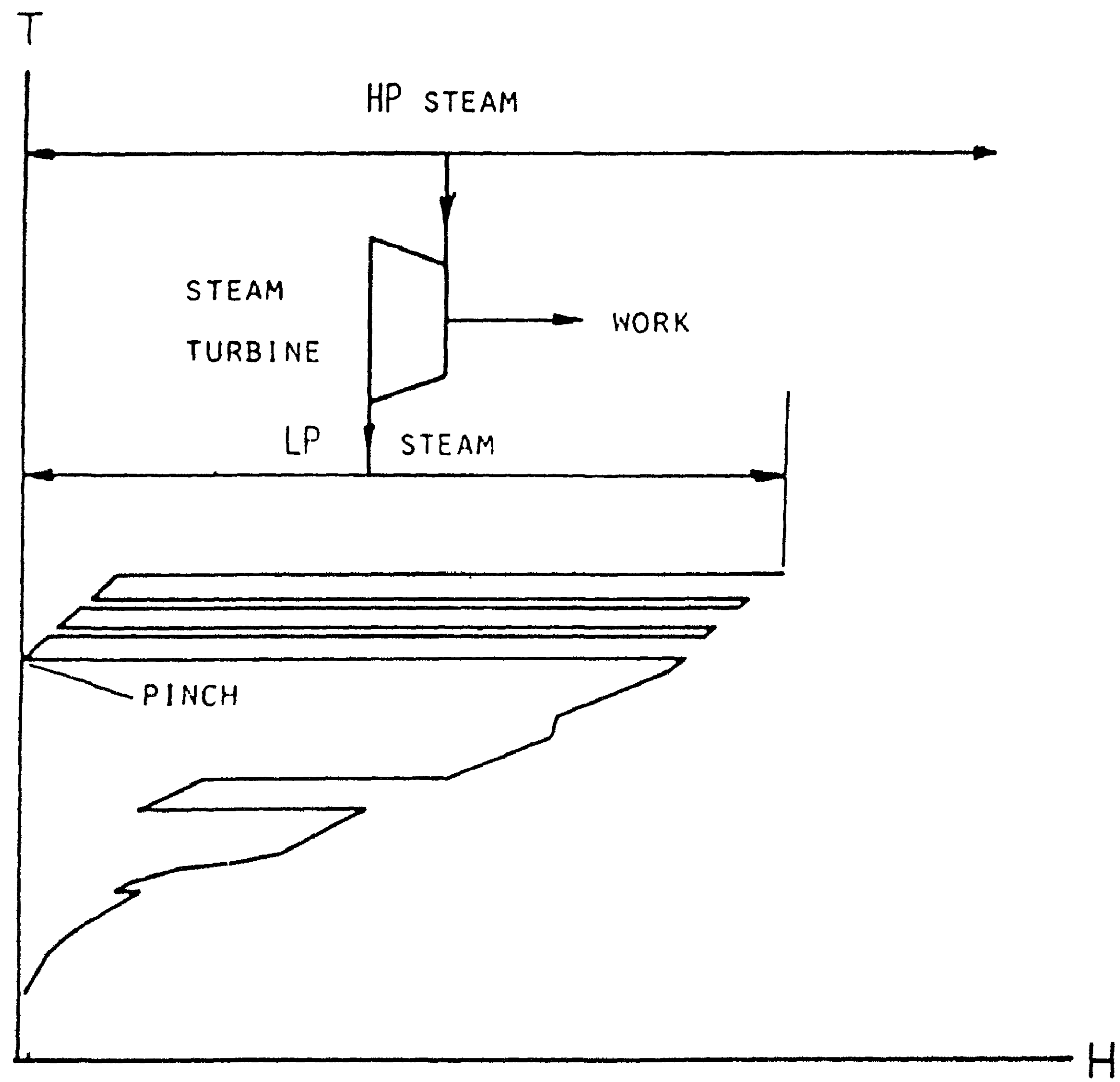


B) THREE EFFECT EVAPORATION

MULTIPLE EFFECT EVAPORATION (Contd.)

- OPTIMUM NUMBER OF EFFECTS CAN BE ESTABLISHED BASED ON

1. INFEASIBILITY OF USING VAPORS AGAINST JUICE / OTHER HEATING DUTIES
2. USE OF BLEED VAPORS FOR EVAPORATION / HEATING
3. CONSTRAINTS OF DISTANCE, PRODUCT CONTAMINATION, SAFETY
4. DEGREE OF CRISS CROSS HEAT TRANSFER
5. REQUIREMENT TO USE STEAM FOR PAN EVAPORATION
6. CAPITAL / ENERGY AND CAPITAL / CAPITAL TRADE OFFS
7. COGENERATION



INTEGRATION WITH THREE EQUAL EFFECTS

GENERAL RECOMMENDATIONS

EXISTING PLANTS

- DATA DERIVED FROM ACTUAL EVAPORATION CONFIGURATION SHOULD BE USED
- CRISS CROSS HEAT TRANSFER ALLOWED FOR ACHIEVING TARGETS AND SIMPLIFY FLOWSHEETS
- VAPOR BLEEDS SHOULD BE USED STRATEGICALLY FOR JUICE HEATING
- FOR CANE SUGAR FACTORY, PAN EVAPORATION CAN BE CARRIED OUT BY STEAM
- PAN VAPORS CAN BE CONDENSED AGAINST COOLING WATER WITHOUT AFFECTING TARGETS
- COGENERATION YIELDS SIGNIFICANT BENEFITS
- REDUCTION IN BPR TO THEORETICAL VALUES CAN SAVE ENERGY

GENERAL RECOMMENDATIONS

EXISTING PLANTS

- FOR TRIPLE EFFECT EVAPORATION CASE :
  - FIRST AND SECOND EFFECT VAPOR SHOULD BE USED ONLY IN NEXT EFFECT, SENSIBLE HEATING ABOVE PINCH
  - STEAM SHOULD BE USED FOR FIRST EFFECT AND FOR FINAL JUICE HEATING
  - FIRST AND SECOND EFFECT VAPORS SHOULD NOT BE CONDENSED AGAINST COOLING WATER

NEW PLANTS

- NUMBER OF EVAPORATION EFFECTS
- DESIGN OF COGENERATION SYSTEM

CASE STUDY

REFINING OF RAW SUGAR

(TATE & LYLE SUGARS, U. K.)

BACKGROUND

- SUGAR REFINERY : PROCESSES RAW BROWN SUGAR TO 99.9% PURE SUGAR

- UTILITIES USED :

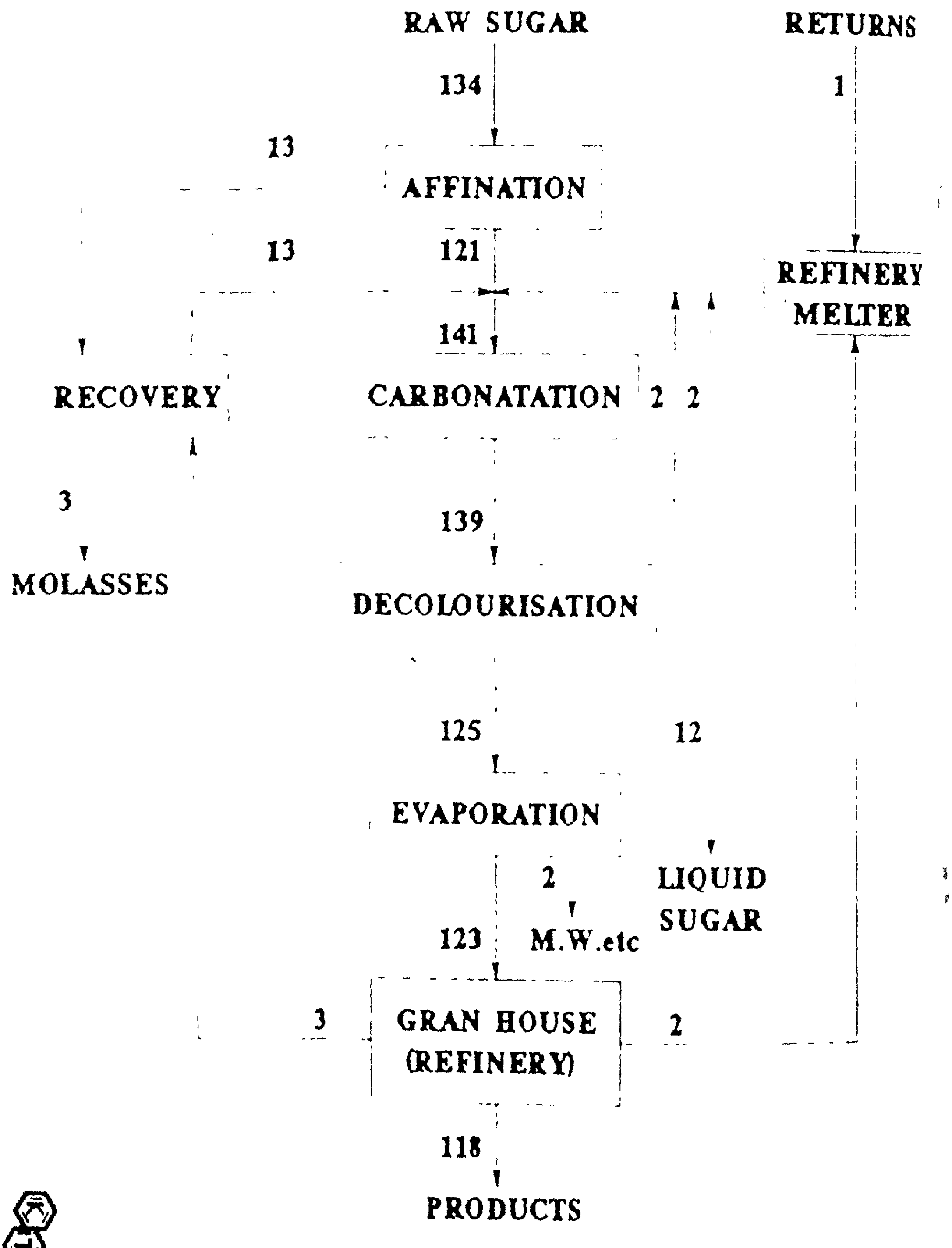
  POWER : 70 KWH / T OF SUGAR

  STEAM : 0.75 T / T OF SUGAR

- CAPTIVE POWER GENERATION USING STEAM TURBINE
  - STEAM AT 40 BAR
  - EXTRACTION AT 4 BAR FOR PROCESS HEATING

- PLANT CAPACITY : 135 T / H

PROCESS FLOW SCHEME



STEPS FOLLOWED FOR PINCH ANALYSIS

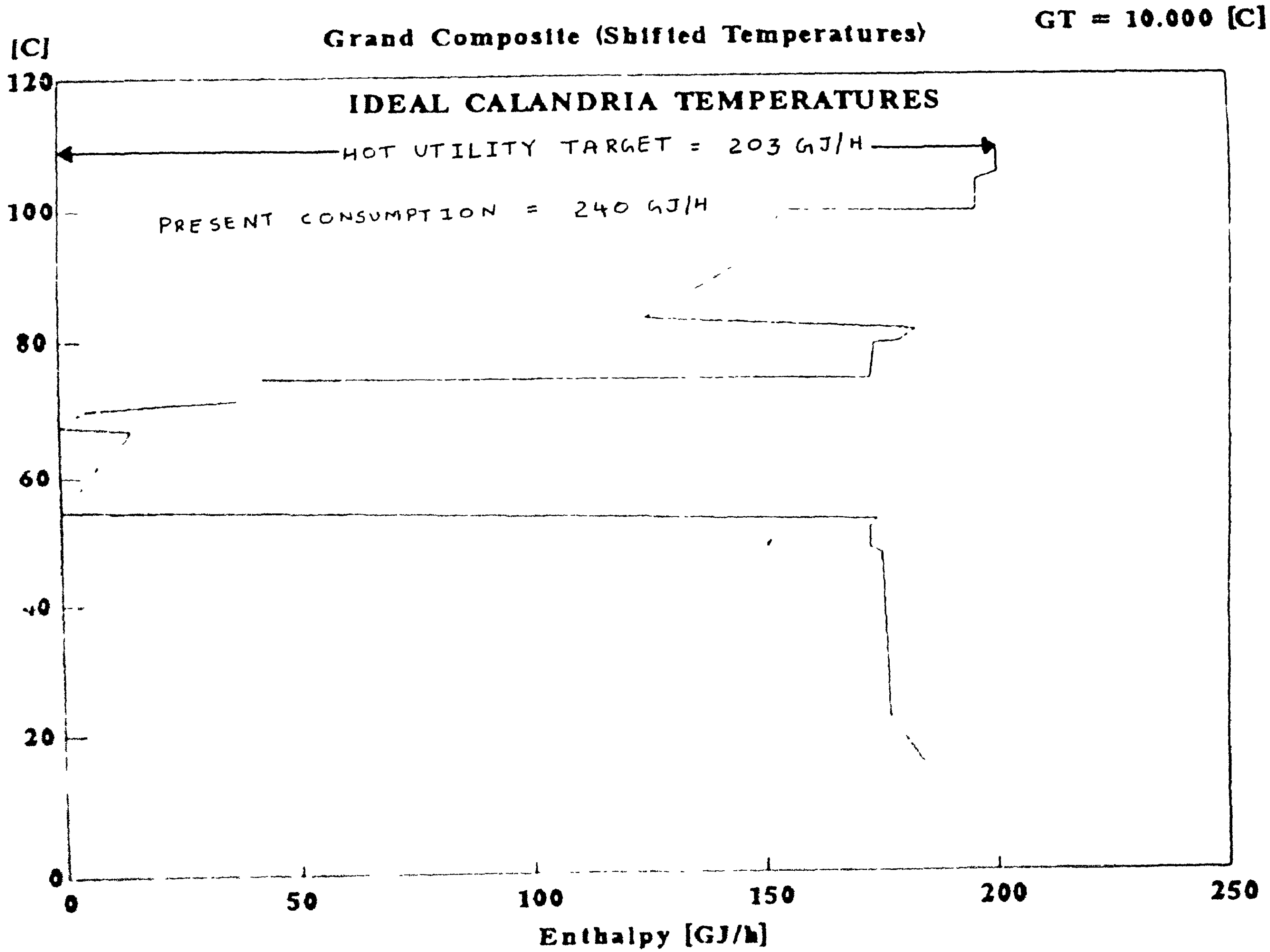
- PINCH ANALYSIS AND TARGET SETTING
  - SCOPE FOR ENERGY SAVINGS
- PROCESS MODIFICATIONS
  - PROCESS CHANGES
  - INTEGRATION OF NEW DEVELOPMENTS
- COMBINED HEAT AND POWER
  - FUTURE EXPANSIONS
- DESIGN OF HEN
  - PRIORITISE BASED ON COST BENEFIT ANALYSIS
- TIME DURATION : 16 WEEKS

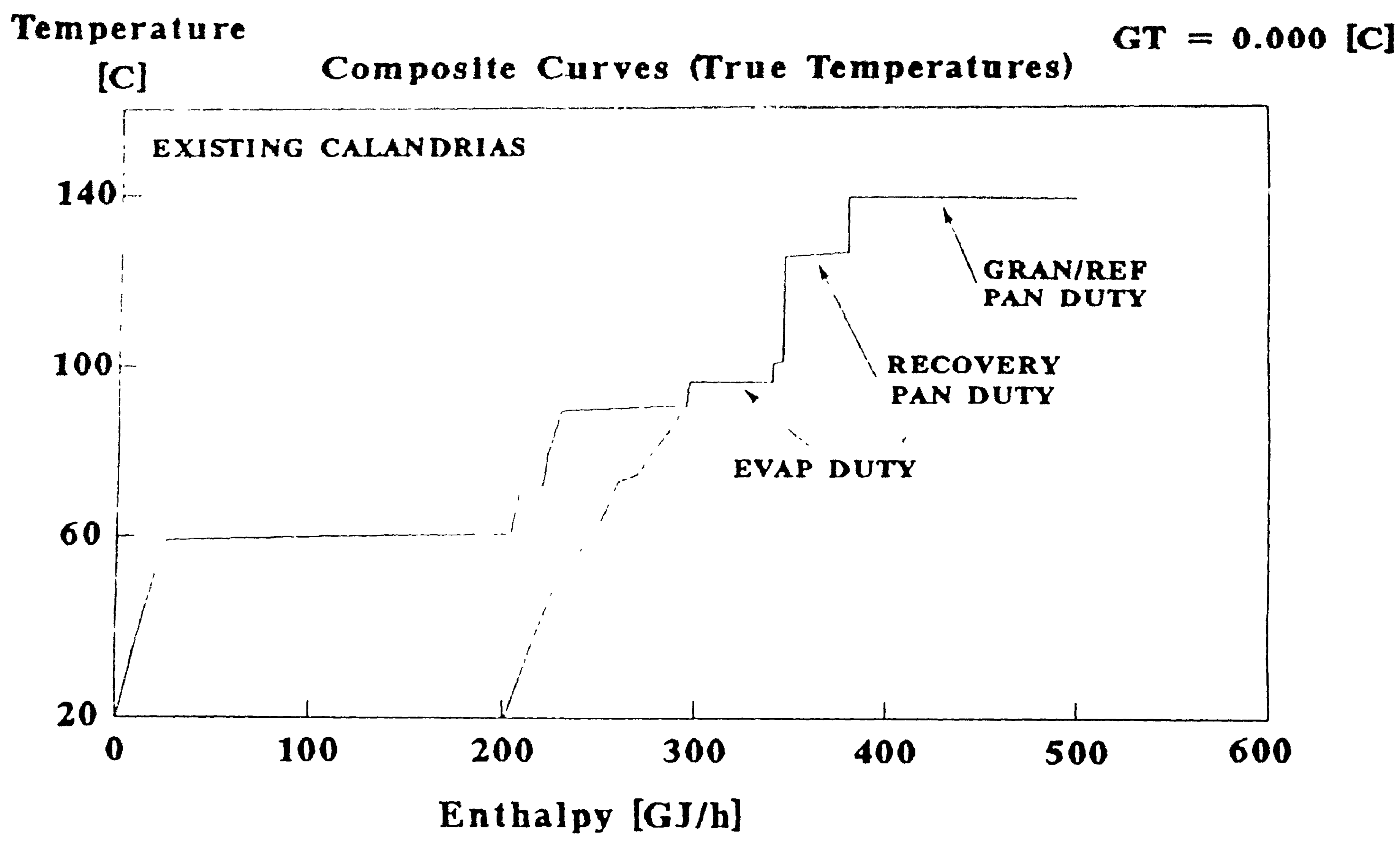
BASIC TARGETS

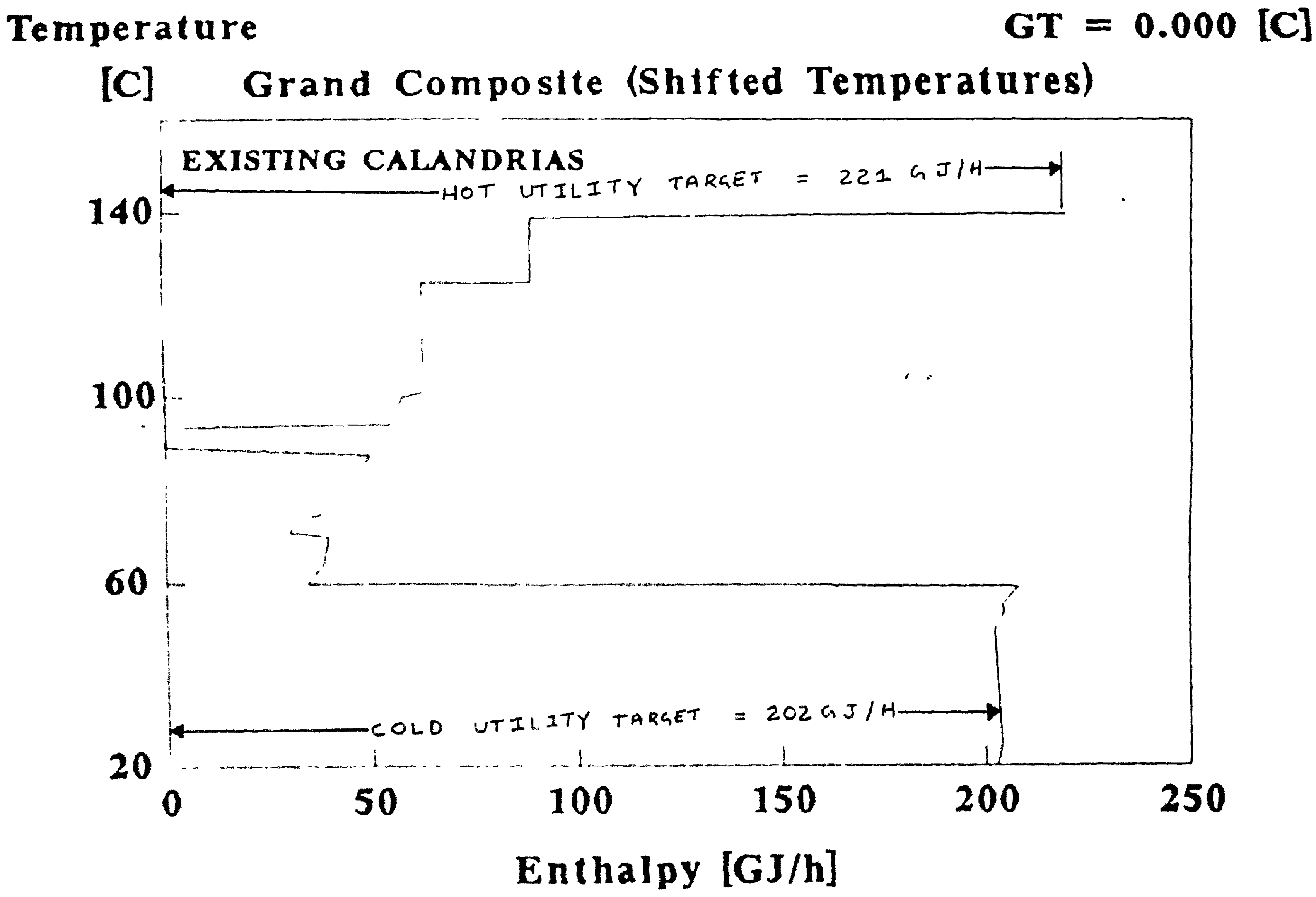
- STREAM DATA CONSISTS OF
  - 31 COLD STREAMS
  - 18 HOT STREAMS

- MAJOR COLD STREAMS
  - LIQOUR EVAPORATION - 47 GJ / H
  - PAN EVAPORATION - 162 GJ / H

- MAJOR HOT STREAMS
  - EVAPORATOR VAPORS - 47 GJ / H
  - PAN VAPORS - 174 GJ / H


Grand Composite (Shifted Temperatures)
GT = 10.000 [C]
IDEAL CALANDRIA TEMPERATURES
HOT UTILITY TARGET = 203 GJ/H
PRESENT CONSUMPTION = 240 GJ/H
[C]
120
100
80
60
40
20
0
0
50
100
150
200
250
Enthalpy [GJ/h]


Temperature
[C]
Composite Curves (True Temperatures)
GT = 0.000 [C]
EXISTING CALANDRIAS
140
100
60
20
GRAN/REF
PAN DUTY
RECOVERY
PAN DUTY
EVAP DUTY
0
100
200
300
400
500
600
Enthalpy [GJ/h]


Temperature
GT = 0.000 [C]
[C]
Grand Composite (Shifted Temperatures)
EXISTING CALANDRIAS
HOT UTILITY TARGET = 221 GJ/H
COLD UTILITY TARGET = 202 GJ/H
140
100
60
20
0
50
100
150
200
250
Enthalpy [GJ/h]

BASIC ENERGY TARGETS

Existing plant configuration 135 t.p.h.

	Utility Hot	Cold	Process Steam
Target and Cross Pinch	240 GJ/h		101 t/h
Actual Steam Demand	286 GJ/h		121 t/h

Targets 135 t.p.h.

	Utility Hot	Cold	Process Steam
Ideal Calandrias	203 GJ/h	184 GJ/h	86 t/h
Existing Calandrias	221 GJ/h	202 GJ/h	94 t/h

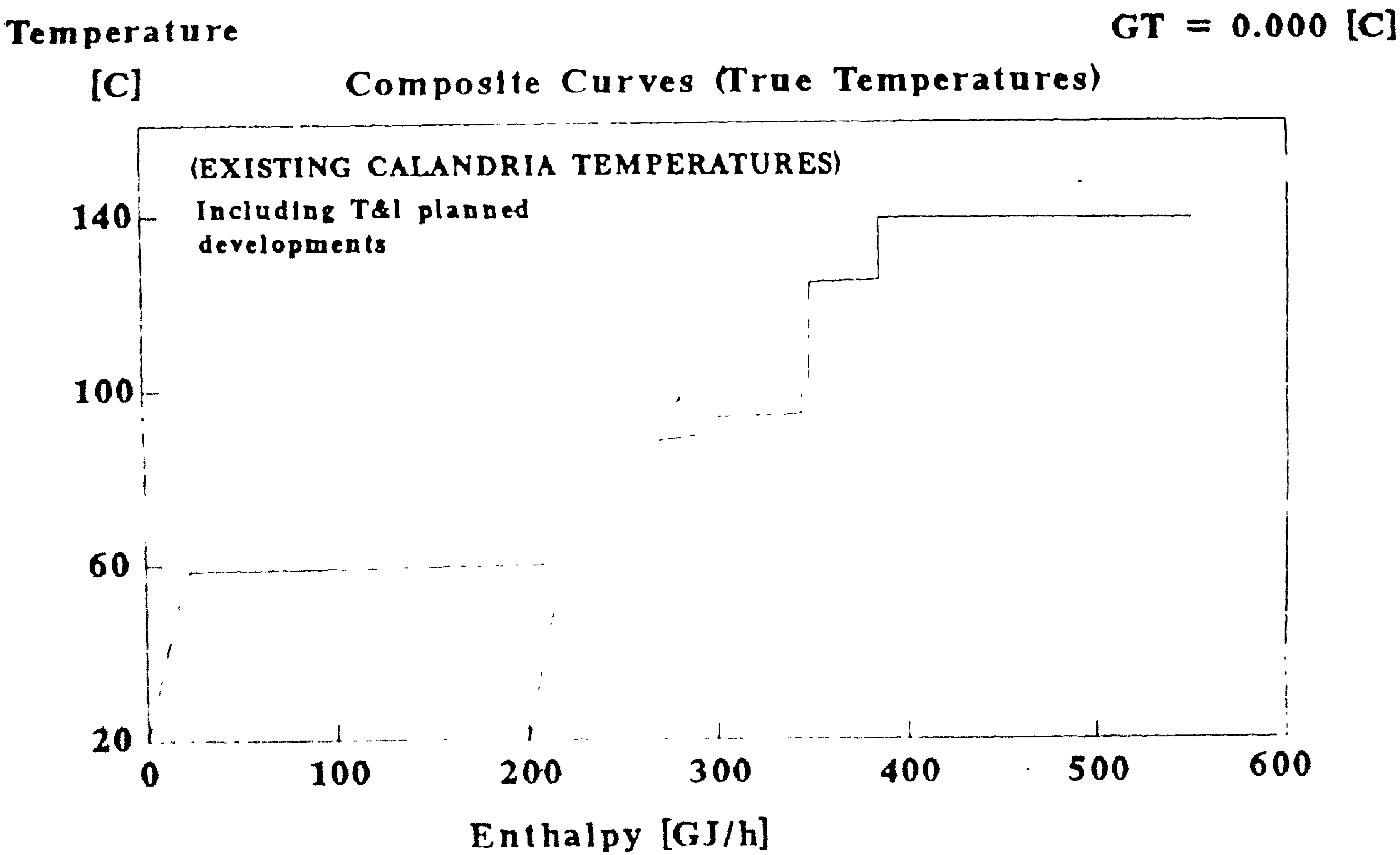
SAVINGS BY PROCESS MODIFICATION

Process Modification	Reduction in Heat Target GJ/h
2 Effect Evaporation	15
3 Effect Evaporation	24
Increase 1st Boiling feed to 80 °Bx	13
Increase 2nd/3rd/4th boiling feed to 80 °Bx	28
Use unevaporated liquor for brixer dilution	17
Increase pan yield (esp. 1st boiling)	Not evaluated
Two effect pans	67
Modify pan calandrias to use 1.7 barA steam	2.2 MW extra power
Heat pump (evaporator vapour compression)	30

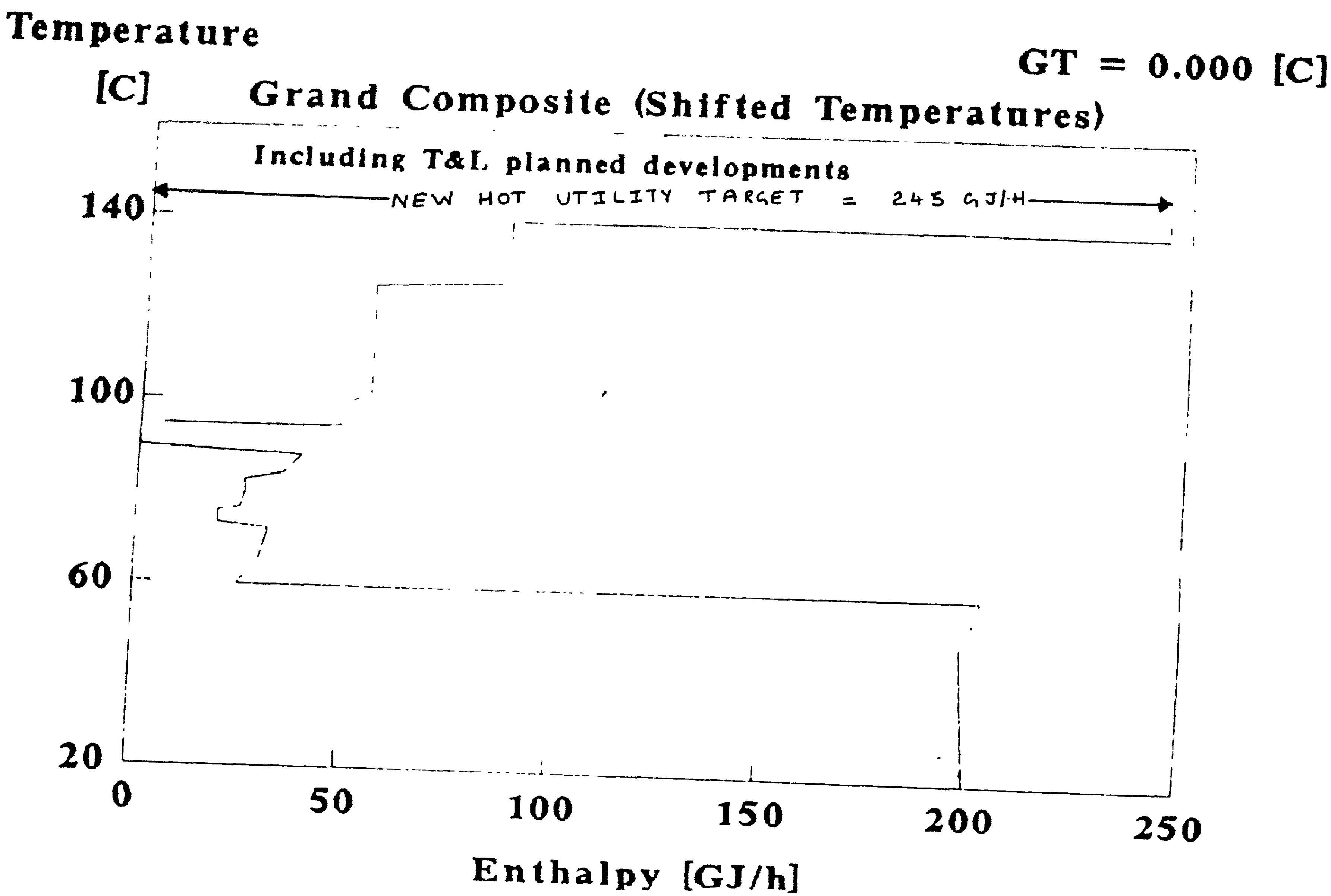
INTEGRATION OF NEW DEVELOPMENTS

PLANNED PROCESS IMPROVEMENTS

- INCREASED CARBONATION TEMPERATURE (82 ^{o}C)
- SWITCH OF SALES LIQUID SUGAR TO CRYSTALLINE SUGAR
- NEW BULK SUGAR PROJECT
- SITE RATIONALISATION



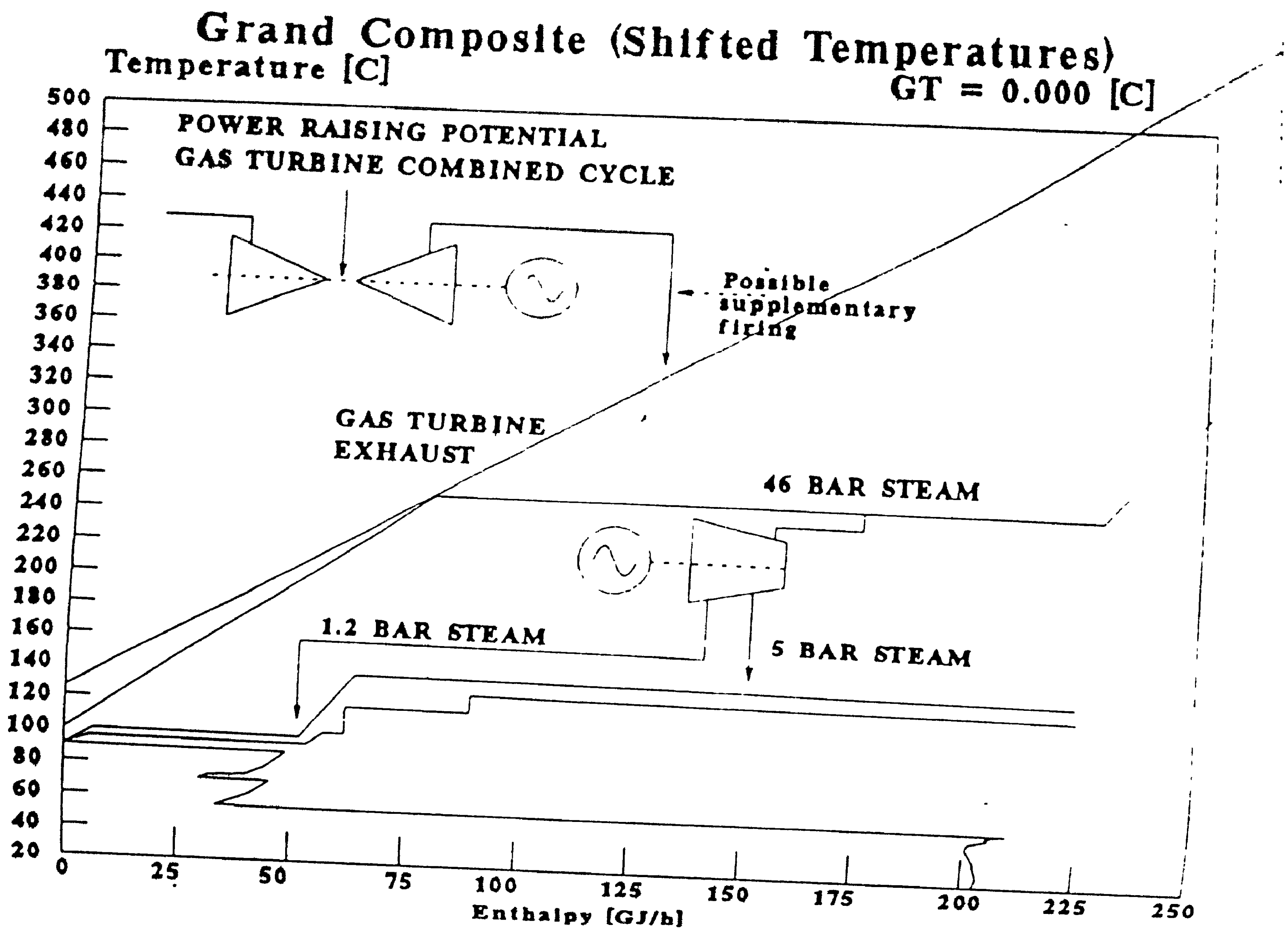
Temperature
[C]
GT = 0.000 [C]
Composite Curves (True Temperatures)
(EXISTING CALANDRIA TEMPERATURES)
Including T&I planned
developments
140
100
60
20
0
100
200
300
400
500
600
Enthalpy [GJ/h]



Temperature [C]
GT = 0.000 [C]
Grand Composite (Shifted Temperatures)
Including T&L planned developments
NEW HOT UTILITY TARGET = 245 GJ/H
140
100
60
20
0
50
100
150
200
250
Enthalpy [GJ/h]

CHP PROJECTS

	SYSTEMS	Steam HP t/h	LP t/h	Steam Turbine MW	Gas Turbine MW	Total Gen. MW	Use MW	Export MW	Payback Years
1.	65 Bar Gas Fired Boiler and new Steam Turbine	103	103	15	–	15	9	6	4.5
2.	6MW Gas Turbine and LP Waste Heat Boiler	89	103	8.9	6	14.9	9	5.9	4
3.	6MW Gas Turbine and HP Waste Heat Boiler	103	103	9.5	6	15.5	9	6.5	3.9
4.	6MW Gas Turbine and HP Waste Heat Boiler + Suppl'y Firing	103	103	9.5	6	15.5	9	6.5	3.4
5.	6MW Gas Turbine and HP Waste Heat Boiler and add'n 6MW Steam Turbine	103	103	10.1	6	16.1	9	7.1	4.2
6.	8 x 6MW Gas Turbines and HP Waste Heat Boilers	103	103	9.5	48	57.5	9	48.5	3.4

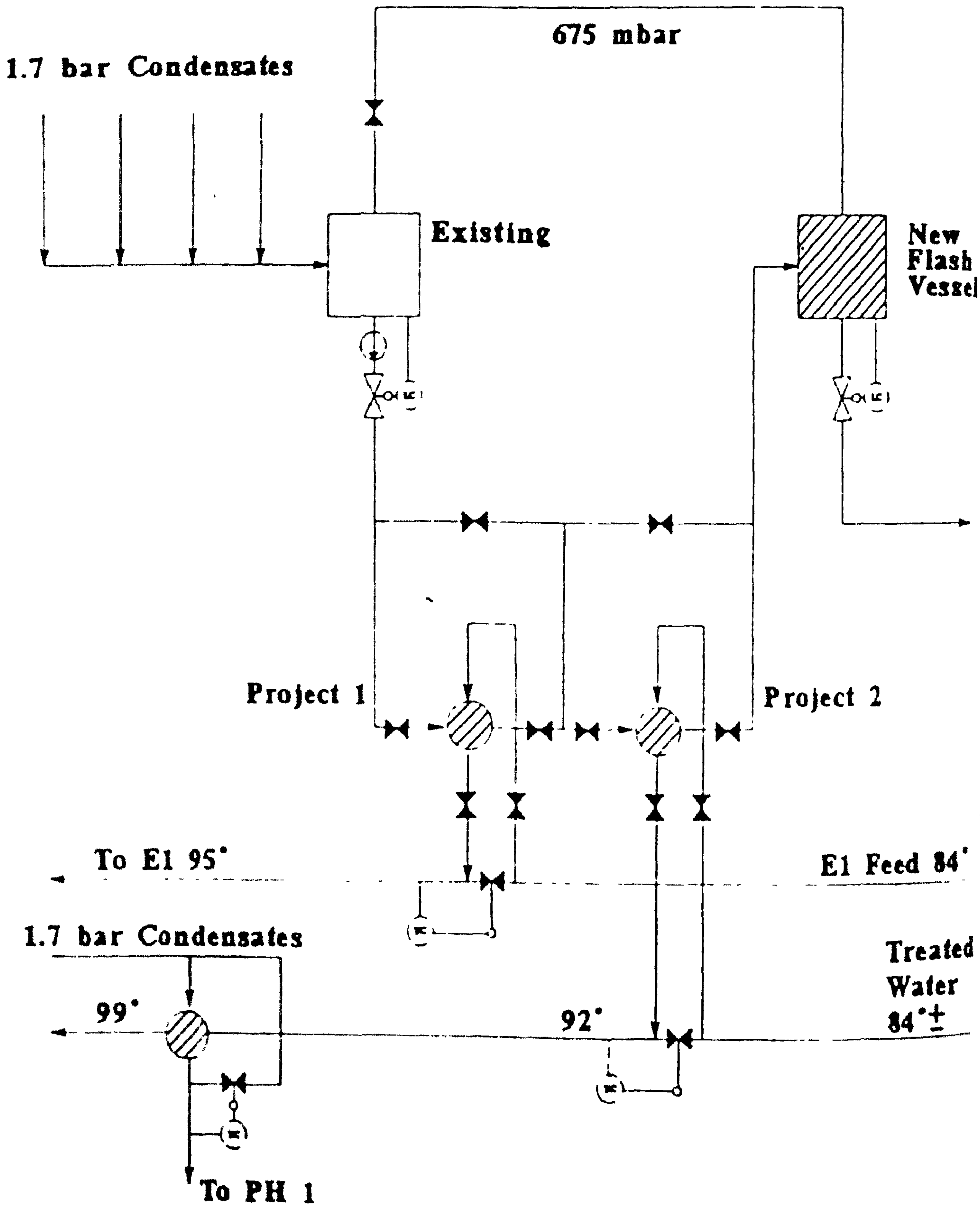

Grand Composite (Shifted Temperatures)
Temperature [C]
GT = 0.000 [C]
POWER RAISING POTENTIAL
GAS TURBINE COMBINED CYCLE
Possible
supplementary
firing
GAS TURBINE
EXHAUST
46 BAR STEAM
1.2 BAR STEAM
5 BAR STEAM
Enthalpy [GJ/h]
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
25
50
75
100
125
150
175
200
225
250

SUMMARY OF FINDINGS PHASES 1, 2, 3

1. 19 GJ/h can be saved by improved heat recovery.
2. 37 GJ/h can be saved by modifying some crystallisers.
3. 10 GJ/h at least can be saved by reducing miscellaneous losses.
4. Reconfiguring evaporation plant can save 15–24 GJ/h.
5. Increasing liquor density feeds to crystallisers can save up to 40 GJ/h.
6. Raising extra power by a new steam turbine and low pressure crystallisation can save 30 GJ/h.
7. Significantly more power can be generated in an energy efficient manner by new C.H.P schemes.

ELIMINATION OF STEAM CONDENSATE FLASH

PROJECTS 1, 2 & 3



Energy Conservation in Cane Preparation And Milling Operation

AVR Reddy
Tamilnadu Sugar Corporation Ltd.

ENERGY CONSERVATION ON CANE PREPARATION AND MILLING IN CANE SUGAR INDUSTRY

BY

A.V.R. REDDY
CHIEF SUGAR ENGINEER
TAMIL NADU SUGAR CORPN.LTD.

******

Economic growth of any country largely depends on reliable and efficient infrastructural support. India, whose economic growth is picking up, saw the economy grow at a rate of 5.7% during 7th Five Year Plan and 6.5% during 8th Five Year Plan and have projection to achieve a target of 7% during the 9th Five Year Plan. In order to achieve the target the infrastructural support in inevitable. Among the required infrastructure, power calls special attention particularly in view of the fact that of late the growth in power supply capacities has not been keeping pace with demand.

The ambitious expectations by the Inter-ministerial working group on power and the conservative estimates by the Planning Commission for the additional power generating capacities are furnished in Annexure-A. This estimate of additional capacity of 40245 MW. to the existing of 84912 MW. has to be achieved by March, 2002 with lot of pre conditions.

The demand for electricity in the year 2001-02 as estimated by the 15th electric power survey is placed at 488.322 billion KWH, including the T & D losses it rises to 569.65 billion KWH. The 15th power survey also estimated the energy requirement as 781.86 BKWH during 2006-07. Energy shortages of 6.2% and peak demand shortage of 20% are expected.

Realising the difficulty behind the conventional power generation to achieve the target, the Govt. of India had initiated suitable action for power generation through Non conventional Energy Sources to reduce the gap between supply and demand. The renewable energy potential in our country is estimated to be about 1,26,000 MW. which includes:

Wind	-	20000 MW.
Small Hydro	-	10000 MW.
Bio-mass/Bio-energy	-	17000 MW.
Ocean, Geo-Thermal Tidel & Wave Power	-	79000 MW.

Of all the non conventional energy sources, the energy from Sugar Industry (Bio mass) seems to be readily available and [illegible] around 3000 MW. could be tapped from all the existing sugar mills in the country through Co-generation. The co-generation at sugar mills is gaining momentum. The MNES has declared attractive incentive schemes to augment co-generation from sugar mills.

With the ever growing energy demand one can easily understand the time required for achieving the targetted [illegible]. However, by reducing the wastages and losses, the gap between supply and demand could be reduced considerably. Thus, energy conservation has become one of the prime objective to the Industries.

The MOP through its energy conservation cell has formulated several energy management programmes and ensure effective implementation through several co-ordinating agencies.

Government of India has made the eneergy audit mandatory for the Industries consuming H.T. power of 500 KVA and above. Soon the Energy Wing will also become powerful like Pollution Wing to implement the norms prescribed.

All of us know that energy saved is energy produced. Every unit of power saved or every kg. of bagasse saved is an additional revenue to the Sugar Industry. There exists lot of scope for energy conservation in Sugar Industry.

Sugar Industry is one of oldest industry and occupies the second largest position in India Sugar by its unavoidable position in the food culture of people all over the world has occupied a pre-dominate position for its manufacture. For all Industrial products there exists a correlation between the power consumed to the commodity produced. For sugar, even though the correlation exists no one took a notice of it because of abandunt availability of power and fuel. So sugar mills are very liberal in consuming more power and fuel. However, the present day energy crisis has warranted to reconsider the energy usage in the Industry.

In the earlier days of the Sugar Industry ie. around 1950 Boilers were operated at a very low pressure to generate steam to drive the prime movers mostly steam enginees for driving the cane

Carrier, Leveller, Cutter, Mills and even pumps too. The electric power requirement was very little and was met by the Electricity Board supply.

Sugar Industries commenced in 1950 initiated power generation restricted to their Inhouse requirement. During this period Turbines were introduced for Mill drives, power generation and electric motor drives for cane preparations. The cycle of operations was around 14 kg./sqcm. (9). The effeciency of steam generation and utilisation were very low. This necessiciated the use of additional fuel like, firewood, furnace oil, etc.

Then, slowly the cycle of operation was increased to 21 kg./sqcm. (g) 340 Deg.C. at this position the industry striked a balance between the energy requirement and the energy production of Bagasse. The dependency on external fuel and external power (EB power) was restricted only for starting. Thus the industry has become self-sufficient in Energy.

However, the present day concept of Co-generation, increasing value for bagasse have driven the sugar mills to adopt stringent energy conservation measures to augment the profits, which help the mills to meet the increasing cost of production.

The Installed power for a 2500 TCD plant is given in Annex. 5. It may be seen that around 37.5% of the total installed power is taken for Cane preparation and Milling. Among these two, cane preparation units take away around 12.5% and Milling tandem 25.0% installed power.

It is a subject for discussion whether the amount of power spent for preparation and Milling is justifiable. Some Engineers and Technologists urge that the excess energy spent for achieving higher preparation will be compensated through reduction in power consumption at Milling.

The extraction of sucrose is a function of defibration or disintegration of the cane tissue, thus proper extraction of juice is only possible when this tissue is ruptured to the greatest possible extent and the juice holding cells are opened up so as to ensure maximum feedability to the mills to achieve higher capacity crush and higher extraction.

The installed power details for cane preparation and milling for a 2500 TCD plant is given in Annexure-C. There are several combinations of preparatory devices installed to achieve higher preparations, some typical combination generally adopted one produced in the enclosed figures.

Every one knows the difficulty in crushing the cane in unprepared way as a whole stalk. Hence, the preparations of cane prior to feed to the mills has become inevitable. The degree of preparation has a definite impact on the capacity. This can be very well understood from the variations in bulk density of cane as given below:

Whole cane more or less tangled	..	125 - 150 kg.cum.
Prepared cane (by knives & shredder)	..	250 - 300 kg.cum.

It has been observed that high degree of preparation results in (1) Enhanced capacity of cane crush (2) Improvement in Extraction.

The degree of preparations is measured by the preparatory index which indicates disintegraty of fibre.

In order to achieve the higher operating results, how much power could be spend is the real question stand before us. The quality of preparation depends on the following factors.

1. Quality of cane
2. Cane mat position in the Cane Carrier
3. No. of preparatory devices
4. Power expended

The quality of cane does affect the power consumption. As seen from the structure of cane it could be observed that the hard rind portion covers the soft fibre and pith. While fresh cane undergoes preparation easily, the staled cane is little bit hard to break because the rinds get dried when staled.

The positions of cane in the carrier also affect the capacity. It is briefly illustrated in Annexure-D. It may be [illegible] that a 10% increase in capacity could be achieved by parallel loading of cane. This parallel loading of cane is not possible by grab unloaders, but possible by sling type unloading and hydraulic tipper unloading in which the power consumption also is said to be around 60% of the total power consumed by Grab system.

The degree of preparations largely depends on the No. of preparatory devices and their combinations located prior to the milling tandem.

The following combinations are adopted in Indian Sugar Mills.

1. Kicker, Leveller, Cutter
2. Kicker, Leveller, Fibrizor / Shredder
3. Kicker, Leveller, Cutter, Fibrizor / Shredder

While all the devices are popular among Indian Engineers, the shredders which delivers high preparatory Index are yet to become popular in Indian Sugar Mills.

It is advocated that shorter the MILLING TANDEM, higher preparation is required and vice versa. For in a long tandem, part of preparation is carried by the mills itself. But in shorter tandem these chances are less hence the cane requires full preparation before being admitted into the mills.

The standard specification advocates two types of cane preparations for 2500 TCD Plant which is furnished in Annexure-E.

In both the cases the P.I to be achieved is stipulated 85 +. The specific power in both the cases assuming 14% fibre and 70° loading, comes to 30 KW. / TFH and 33.5 KW./TFH. which is quite sufficient for a P.I. of 85 and 85+. A comparision of P.I. to be obtained against power consumption is given in Annexure-F.

Hence, a good selection and combination of preparatory devices should be done by positioning the power consumption as basic criteria.

The sharing of total installed power among a combination of preparatory devices not widely differs. Generally, around 7 to 10 KW./TFH is taken for Leveller and the balance power is added to the Shredder / Fibrizor.

The power absorbed by the Cane preparatory devices depends on

1. Tonnage of Cane
2. Fibre and nature of Cane
3. Proportion of cane actually cut (clearance)
4. The No. of blades
5. Speed of rotation
6. Radius of cutting circle
7. Clearance between tip to Carrier / Anvil
8. Variable factors like,
   a. Friction
   b. Lubrication
   c. wear on knives/hammers

The following inferences from detailed study conducted by Australian Engineers on the functioning of shredder could aptly [illegible] the effects of influencing factors.

1. The effect of cane rate on Preparatory Index is insignificant of 25% increase in through-out.
2. Varietial effects do exists but do not affect the power measurement.

For cut-chop cane, the effect of pre-knifing the cane was only significant if the P.I. by shredder alone was below 75 with shredders giving P.I greater than 80, pre-knifing had little effect (This is not true for whole stalk cane).

Full coverage of the grind by hammer faces is essential to good preparation. The No. of rows of hammers has only a marginal effect on P.I. But changing the No. of hammers in a row can reduce the P.I. by 4-6 points.

Hammer mass has an insignificant effect on P.I. However heavy hammers are required to withstand the force for breaking the full cane.

Operating speed has a significant effect on preparation P.I. increases by 6 points in going from 900 to 1200 rpm.

The clearance between hammer face and anvil has little effect on P.I with clearance of 12 mm. or less, but with clearance of 20 mm. the P.I. dropped 3 to 4 points.

While the factors like No. of blades, speed, Radius of ing edges and proportion of uncut cane are designed to handle a rticular range of tonnage of cane, fibre % cane and nature of er, the variable factors depend on the maintenance.

Leaving the friction and lubrication aside, as they may lt in a breakdown of equipment when the limit is exceeded, wear on blades and hammers may result in higher power umption and reduction in Preparatory Index.

In the knives, the bluntness causes a hit over the cane mat instead of cutting the cane for which the knives are intended. Whereas, in the fibrizor / shredder the bluntness (out of shape) causes slipping of hammer over the cane mat in the entry as well as on the anvil instead of hitting. At those times, in a shredder installation the cane pieces fall in the carrier without fully prepared and in fibrizor installation cause a stangnation of the cane travel which could affect the functioning of the device prior to fibrizor.

The increase in power could be observed between two reclamations of blades / hammers by hard-facing to the original profile. It is observed that around 25% to 30% increase in power between the worn-out and new blades. Hence, periodical check-up to sharpness and edge building of blades / hammers should be done to avoid excess power consumption. A fall in Preparatory index is a good indication of such cases.

It is always better to operate the devices at higher efficiency to get a better power efficiency ratio. To establish better power efficiency, the feeding of cane to the devices should be more or less constant. Having fixed the width of the [illegible] in terms of width of the carrier, the variables are the height of the cane mat and the speed of the carrier.

By an effective cane handling system and by an efficient cane kicker a more or less constant height of cane mat can be established. The speed of the carrier can be controlled based on the limiting load of the cane preparatory devices. As the cane

preparation and crushing are continuous processes, the speed can also be controlled through Ist Mill loading with over-riding facility for overloading signals of preparatory devices.

Generally the nominal power consumed by the devices will be 60% to 70% of the installed power. Whereas, the maximum peak power is 175% of the installed power. The case of maximum peak power situation arise at times when the devices handle tramp iron, except for that the device would be operating between minimum to installed power. Our aim is to operate the device at maximum efficiency with less loss of power.

This could be possible when we install a suitable drive system to the device to operate according to the needs and the power consumption could be restricted to the work done.

Normally the drives for the preparatory devices are either single stage steam turbines or electric motors. However, the leveller is usually driven by an Electric motor.

It is obvious that in this emerging situation of energy conservation single stage steam turbines are being outdated because of their higher steam consumption and low efficiency. Electric motors of various designs are occuping the place of single stage steam turbines.

Hence, it may be considered that electric motors are best suitable drives for cane preparatory devices.

It has been observed that the mean power absorbed varies around 60 to 70% of the installed power. For practical reasons the selection of drives are done like that. However, by ensuring constant level of feed with clean cane, we may reduce the gap considerably between the installed and actual power. Practical experience shows that actual factory conditions does not permit such ideal situation and force to adhere to adopt this variation, considering a safety margin and accommodating the efficiency of the motor.

The torque requirement of the devices has a choice to choose the slip ring induction motor. The standard specification specifies motors with 15% slip for leveller. The power consumption of the motor depends on the efficiency of the motor, % of loading, applied voltage, ampere and the power factor.

It may be noted that the efficiency drastically falls down when the motor runs at partial load.

There will not be frequent variation in the voltage, however [illegible] voltage more than the specified voltage at name plate, results in [illegible] increase of magnetisation losses. The [illegible] in applying rated voltage to the motor just enough [illegible] "work task", thereby minimising the losses which would have been otherwise dissipated as heat.

One of the biggest drawbacks of non-synchronous motors is [illegible] low power factor. Like the efficiency, the power factor of induction motors varies with speed, power and load.

The power factor always decreases as the same time as load. it starts slowly and then rapidly, at no load the power factor is only 0.2 It is a pity to mention that such an important factor is almost neglected in practical conditions by factory personels.

The following are the drawbacks of low power factor.

a. Under utilisation of the Alternator.

b. Increase in losses through joule effect.

c. Increased voltage drop in the alternator and the lines.

3. Decrease in efficiency.

In order to improve the power factor one among the suitable way to suit the operating condition, is to introduce capacitors, either at the panel board or preferably at the motors which are responsible for lower power factor.

The introduction of capacitors alone does not relieve from the problem, but proper maintenance. Periodic checks should be done for effective functioning of the capacitors. The normal power consumption of the Capacitor is 1 to 3 watts / KVAR, any excess consumption indicates loss of power.

We have already indicated that the drive and control systems should be selected to optimise the power consumption. It is also noted that only 60% of the installed power is consumed. Hence, the drives run around 60% load, which may cause a decrease in efficiency. In order to avoid this, now-a-days soft starts are used.

Soft starters put in the startor circuit cannot replace Grid resistance starters (GRS) because with low starting voltage and low rotor resistance the slip ring motor will not be able to develop the desired starting torque and the starting current will be high.

However, soft starters can be used along with GRS such that high starting torques is achieved by GPS while energy saving is achieved with soft starter at light loads.

It may be asserted that besides a good selection power spent [illegible] Cane preparation depends on so many variables which could be very well arrested by effective monitoring and good operative techniques.

It should also be remembered that by good preparation, the [illegible] is eased considerably.

Milling

The completion of the extraction process, which has been initiated by the cane preparatory devices, is accomplished by the cane mills. There exists two distinct processes for seperation of juice and bagasse, viz., (1) Milling (2) Diffusion.

From the subject point of view, we restrict our comments upto Milling. Milling is basically an exercise in material seperation. Cane which consists fibre (solid) and juice (liquid) have to be seperated before sugar is produced. This is done in a Milling tandem in which juice is expelled from the fibre by

successive application of pressures as the cane passes through pairs of rollers.

Basically, a mill means a conventional three roller mill, with drive fitted to the top roller, the feed and discharge rollers driven through pinions from top roller, fitted with usual attachments like trash plate, scrapper plate, messchart knives, etc. and supported with Bronze / White metal oil lubricated water cooled bearings.

A milling tandem is designed for a nominal capacity at a nominal juice recovery. That is, the tandem should accept the quantity of cane desired in a unit time and expel a targeted a quantum of juice. Hence, it is worth to mention that the capacity and extraction are two deciding factors for explaining the performance of the milling tandem.

The extraction in milling is influenced by,

1. Fibre content of cane.
2. Size and speed of the mills
3. No. of squezes (No. of mills)
4. Degree of preparation
5. Effective pressure applied
6. Drainage
7. Imbibition
8. Mill settings

The capacity of a tandem is determined by the ability of the rollers to accept the cane presented and transport it by friction between the rollers. This is called feedability.

Before we move on to the power consumption and conservatio let us briefly discuss the factors influencing the capacity an extraction.

During crushing, the resistance offered by the liquid i negligible and hence the entire power is spent, only to over com the resistance offered by the fibre. Hence, the total quantit of material received at the mills is closely proportional to th fibre and also the power consumption.

The product of the escribed area and the thickness o bagasse layer decides the quantity of bagasse to be handled in unit time. The thickness of bagasse is more or less fixed fo each size of mill and tandem length to obtain optimu performance. Hence, the escribed area which is the product o the size [illegible] and speed (N) of the mill, is the deciding facto to obtain the capacity and the performance.

Depending on the quantum of bagasse to be handled and the thickness of bagasse layer, there exists a minimum permissib [illegible] for [illegible] mill. In order to obtain the [illegible] extraction, the No. of mills in a tandem are decided depending o [illegible]. As a guide, in a short tandem, the thickness o bagasse layer [illegible] to obtain a satisfactory extraction, i a long tandem on the other hand, the thickness of bagasse layer is increased.

A good preparation offers a better feedability and less force is required to expel the juice from the ruptured juice cells, which results in better extraction and enhanced capacity for the same power.

The degree of sequeezing of bagasse to expel the juice out of fibre depends on the hydraulic pressure applied. The mechanical strength of the mill is the limiting factor for the hydraulic pressure applied. However, the bagasse requires less power than the limiting factor. The power supplied to the mill drive has to overcome the resistance offered by the mills by the application of hydraulic pressure and shall have to keep the speed of mill constant. While a little high hydraulic pressure results in improved extraction, the feedability and the capacity are reduced, at the same time the power consumption increases.

The main purpose of milling is to extract all the liquid juice from fibre. When proper drainage facilities are not provided the expelled juice is made to contact again with the fibre and reabsorped by the fibre, which is an added load to the subsequent mills in the tandem. Hence, in addition to the regular grooving, messchart grooves, lotus holes on rollers are provided to aid drainage.

By pressure alone, it is impossible to expel much over 90% of the juice from fibre because at some point the solid and liquid phases coalesence into a mass which extrudes forward. Therefore, in order to extract more of the juice, water is added. The water mixes with the juice and a certain percentage of the

diluted juice is expelled in the next pair of rollers. B repeating the process in a sequence manner, higher extraction - achieved. There are several kind of imbibition methods, lik simple, compound, etc. Mostly compound imbibition which i superior to simple imbibition are adopted in all the mills. I was also observed that beyond 250% imbibition on fibre, there i no appreciable improvement in extraction, and at the same tim the load to evaporator increases. It may also be noted tha higher imbibition results in higher extraction at the same tim reduces the feedability and the capacity.

Mill settings: is one of the most important criteria fo achieving best results in a milling tandem. Setting of the mil rollers in a mill at a most suitable position to achiev favourable results depends mostly on the above factors alread discussed. The weight of fibre passing through the mill per unit time is the basis for calculating the proper setting. A proper mill setting performance can be studied from the brix curve Brix curve shall be drawn at regular intervals and the performance [illegible] studied and altered if necessary, based o theoritical curve.

POWER SPENT IN MILLING:

Energy utilisation at mills assume two important factors: one, the conversion of primemover energy into shaft power, tw utilisation of shaft power at the mills.

Utilisation of Shaft power:

The utilisation of shaft power at the mills depends on various factors. The power given to the top roller is consumed by several components, they are:-

1. power consumed by compression of bagasse.
2. power consumed by friction between the shafts and bearings.
3. power consumed by friction between trash plate and bagasse.
4. power consumed by scrappers due to friction against the roller.
5. power consumed by crown pinions.

The distribution of power among the above constituents are as follows:

1.	compression of bagasse	-	64%
2.	By bearings	-	15%
3.	By trash plate	-	14%
4.	Scrappers	-	2%
5.	Pinions	-	5%

While the power consumption by the last 2 items are standard for each tandem, the other 3 items depend on the hydraulic pressure applied and can vary depending on the fibre loading.

POWER CONSUMED BY BEARINGS:

On the conservation point of view, out of these 3 items, the power consumed by the bearings, which is around 15% could be reduced almost to 'nil' by replacing the White Metal bearings to Anti-friction Roller bearings.

Roller bearings for Mill journals are not new to the industry. It was outdated mainly due to the running maintenance problems, as well as due to the cost factor over the white metal bearings which found wide application due to its cheaper cost, easy running maintenance. Now, the time has come to reconsider old views by placing the energy saved by roller bearings over the other costs. SKF bearings has come out with new type of bearing housing and roller bearing fittings which facilitates easy installation, removal and effective oil lubrication.

It also facilitates inter-changeability between top , feed and discharge roller bearings. If this type of bearings and housings are installed to the existing units without much modifications, the energy saving could be around 16% of the total power spent on mills.

POWER SPENT FOR COMPRESSION OF BAGASSE & TRASH PLATE:

The power spent for compression and power absorbed by trash plate due to friction with bagasse, depend on the hydraulic pressure applied to the top rollers and trash plate settings. As already indicated, if higher hydraulic pressure is applied, there [illegible] increase in extraction as well as increase in the power consumption, and also the mill looses the capacity due to poor feedability.

Further, from the point of view of maintenance higher hydraulic pressure results in poor lubrication to Journals. Hence an optimum value has to be struck by considering all the influencing factors.

A recent development of LPE system which consists of a long train of two roller mills running on Roller bearings and operating under low hydraulic pressure eliminates the use of trash plate thus saves power upto 35% .

The system was selected as a long term strategy for implementation after successful output by R & D, by Technology information, Forcasting and Assessment Council (TIFAC), Dept. of Science and Technology, Government of India, New Delhi.

The LPE system is using a train of low pressure (LP) units as main components. Although this arrangement has the resemblance to a conventional mill train and its operation, the process lends itself more towards the solid liquid extraction technology and shall be understood as "Pressure enforced solid liquid extraction".

The system requires a compulsory Cane preparation of 85 +, at which level soluble matter can be easily extracted by lixivation alone. This is due to the fact, that there is a high concentration differenece of soluble matter in between cell content and the extraction liquid. However, with progressing procedure, this effect is becoming more time related.

To accelerate extraction, pressure is then applied in combination with imbibition and maceration, to enforce with this reciprocal, effect the process. The bottom rollers of LP system are provided with holes to facilitate high drainage, which allow to operate with very high maceration and liquid flow rate in

between the cane mass and the solvent. Final dewatering is achieved with conventional 3 roller mill preceeded by a medium pressure Two roller system.

The power requirement of the LPE system as furnished by the promotor for handling 2500 TCD is given in Annexure-G, with a comparision of power installed for a conventional milling tandem. The drive of the LPE system is said to be ordinary Electric motors and the rollers mounted with roller bearings.

It may be seen that there is a reduction of power to the tune of 1100 HP (825 KW.) on the installed capacity. The power saving is around 35%. Besides this power saving, there exists other benefits also, and furnished in Annexure-H.

A comparision of specific power requirement for a conventional milling tandem, a Diffusor and a LPE system is furnished in Annexure-I for reference.

Conversion of Prime mover power into Shaft power:

The prime movers for the mills can be classified into 3 catagories:

1. Steam Turbines
2. Electric Motors (D.C.Motors)
3. Hydraulic drives

Steam Turbines:

The steam turbines replaced the steam engines which were used as mill drives, and stayed in the industry due to its simple design and operational flexibility inspite of its higher specific steam consumption. But today's energy consciousness has warranted its replacement by high efficiency drives.

Presently most of the sugar mills are installed with steam turbines as mill drives. These steam turbines are of lower horse power capacity and axial flow single stage construction. The efficiency of these turbines ranges between 35 to 43%. This low efficiency results these turbines to operate at higher specific steam consumption than the power turbines.

The figure No.3 enclosed shows the power generated at steam turbines shaft and transmitted to a roller shaft through high and slow speed gear box, open gearings stages, couplings and tail bars.

This lengthy power transmission system results in a very low overall efficiency of the order of 31%. The efficiency of various units connected in the power transmission line for a Mill in a tandem is furnished in Annexure-J. The figures are considered based on well maintained and good lubricated bearings. If lubrication is below normal then power consumption may increase steeply.

It is known that the efficiency of steam turbine remains at the optimum level when the input steam parammeters and speed are kept at rated level. One can easily imagine the steam pressure fluctuation occuring in sugar mills and its consequent effect on the efficiency and steam consumption of the steam turbines.

Even by considering a moderate steady steam parameters and speed, the steam driven mills require around 25 to 30% more running power over the actually required, when it comes for installed power again suitable margin of safety had to be added which again increase the power installed by another 25%.

Electric Drives (D.C.Motors):

The electric drives (D.C.Motors) for the mills are better placed than steam drives, in terms of simplicity, better leanliness, ease of control, readily adaptable and integration into any complex system with ease and flexibility. Above all, here is an increase in the efficiency of the system.

The efficiency of D.C.Motor and thyristor convector is about 5% each and the combined efficiency comes to 90% and stands lmost constant for all loading 50 to 100% rated speed.

The efficiency of the mill connected with D.C.Motor is llustrated in Figure 4. It can be observed that the overall fficiency of the system comes to 51%

Here too, except for the elimination of primary high speed reduction gear box, all other items in the tranmission train remain as such, which again calls for a higher power than actually require.

Hydraulic Drives:

Hydraulic drives are not new to sugar mills. Though it has not find its place as mill drives, there were equipments of water hydraulics using wheels to drive the centrifugals through high pressure water and oil driven centrifugals were part of our standard sugar mill machinery upto late 70's and early 80's.

Now, hydraulic drives are finding their way to replace the conventional mill drives. These drives, is a combination of two main components, the pump normally driven by an electric motor and the hydraulic motor, which runs by the displacement of oil. The speed of the motor depends on the rate at which the displacement of oil takes places. The speed can be controlled by varying the flow in a fixed displacement pump and by changing the pump swash angle in a variable displacement pump.

At normal operating condition, a variable volume hydraulic pump (1800 rpm, 90% stroke, 175 bar) has an overall efficiency of 92.5%, the hydraulic motor 93.5% and the usual electric motors around 95%. The overall efficiency of converting electric power into shaft power comes around 82.16%.

Considering a large multistage back pressure turbine and gear box driving a Alternator to produce electric power and

operates at constant speed has an efficiency of approx. 75% and the alternator approx. 95%. Therefore, in the conversion of steam power into electric power for the turbo alternator system, the overall efficiency becomes 71.25%.

Thus the total overall efficiency of converting steam power into shaft power for a hydraulic system is 82.16 % x 71.25 % = 58.54 %. The power transmission by a hydraulic motor in a mill is given in figure 5.

By installing a hydraulic drive directly to the top roller square end of a mill, it is expected to achieve reduction in the power installed to the order of 20%, which otherwise would have been consumed at the transmission system as in other types of Mill drives.

A comparision of all the three types of Mill drives ie. Steam turbines, Electric drives and Hydraulic drives are furnished in Annexure-K.

Achieving maximum power reduction, even though depends so many variables, is also depend on the selection of combination of Cane Preparatory Devices and selection Mill drives.

There are several other provisions / devices which are used to augument the capacity and extraction. These provisions / devices also help to achieve consistent performance, they are:

1. Arcing of rollers
2. Chevron grooves

3. Feeding devices:

a. Donnelly chutes

b. Over feed rollers

c. Underfeed rollers

d. Grooved roller pressure feeders

e. Toothed roller pressure feeders

The arcing and chevron cutting have become part of maintenance activities and carried out at regular intervals to achieve consistent performance.

The feeding devices are used in different combinations depending on the designer / user's choice. It has been accepted that there exists definite increase in capacity in installing these devices. It is considered that around 10 to 15% increase in capacity by installing these devices, which also aid to provide uniform feeding to the mills to ensure optimum extraction and achieve less bagasse moisture. The power requirement for pressure feeders ranges from 10 to 25 % of the connecting mill power and the speed is 30% to 50% more than the peripheral speed of the mill.

Apart from right selection of combination of drives for the cane preparation and milling, the author suggests some simple ways to conserve energy.

Clean Cane:

A clean raw material is much important to get desired output. At present, as per standard norms for trash 10% weight is reduced from the gross weight of the cane. But the trash is not removed from the vahicle but unloaded to the carrier and carried on into the process. The % of trash may vary depending on several factors like, type of cutting, bundling and loading, etc. So it may rightly said that a factory crushing 100 tCH as per record crushes around 110 TCH in actual. This extra 10 tons. is a waste and the power used for crushing this waste also goes as waste.

If the management bestow its attention to ensure 100% clean cane, then this waste crushing can be converted into useful crushing and power can be spent in a useful way.

The possible saving is furnished in terms of reduction in crushing days in Annexure-L.

It may be observed that around 15 crushing days are reduced in a season or a mill can crush 37840 tons. extra in the same crushing days with same power, by ensuring 100% clean cane.

Chopped Cane:

The Australian Mills are using Mechanical choppers for harvesting and send the chopped cane directly to heavy duty shredders and achieve 90+ preparatory index. In India, almost 100% of the cane is manually harvested, which also give scope to

get chopped like cane by manually cutting the whole stalk into 4 or 5 pieces. The transporting to the vehicle could be done through baskets and the vehicles could be provided with elevated screens on both sides to maximise loading. As the chopped cane permits little high bulk density the vehicles could be loaded upto its maximum limit and the chances of trash entering as binders into the cane could be totally eliminated . The unloading can be done through hydraulic tippers.

It has been reported by HUGOT that there exists a marked difference between the power necessary when the canes are delivered in pieces relative to the power normally required for whole cane. The power details furnished in HUGOT is given in Annexure-M.

Hence, the Author suggests that besides considering energy conservation on equipments, the first and foremost activity to achieve energy conservation in cane preparation and milling is to ensure clean cane and admit only the useful portion of the cane into the process. A little effort in this direction can yield substantial benefits to the mills.

ACKNOWLEDGEMENT:

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ANNEXURE-A

I. PROJECTION OF GENERATION OF POWER

S.No.	Description	Hydro	Coal/ Theremal	Oil/ Gas	Nuclar	Total
			(in MW.)			
1.	Capacity as on 1.4.1997	21637	54217	6832	2223	84912
2.	Projection by working	17111	23832	13612	880	37735
3.	Planning Commission Estimates	9820	16097	13448	880	40245
4.	Cap.expected by 31.3.2002 (Add: 1+3)	31457	70314	20281	3105	125157

ANNEXURE-B

Installed Power of a 2500 TCD Sugar Plant

S.No.	Name of the Installations	Under service in HP.	Std.by in HP.	Total in HP.	%
1.	Cane Preparation & Mill House	3532	241	3773	37.5
2.	Boiler & Auxiliaries	1317	251	1569	15.5
3.	Clarification & Evaporation	664	591	1255	12.5
4.	Crystallizers	280	10	290	3.0
5.	Spray Pumps	255	250	505	5.0
6.	Injection Pumps	745	125	870	9.0
7.	B & C Centrifugals	375	150	525	5.0
8.	A-Centrifugals	450	-	450	4.5
9.	Curing & Sugar House	482	140	622	6.0
10.	Misc. (ETP, W/S, Godown, etc.)	162	33	175	2.0
	Total	8262	1791	10053	100

ANNEXURE-C (i)

Power details of Cane Preparation

S.No.	Name of the Installation	Total H.P.	Std.by units (in H.P.)	Under service
1.	Cane Unloaders - 2 Nos.	110	-	110
2.	Feeder Tables	30	-	30
3.	Lub.oil pump - 2 Nos.	4	2	2
4.	Cane Carrier-I	50	-	50
5.	Cane Kicker	50	-	50
6.	Cane Leveller	250	-	250
7.	Cane Fibrizor	700	-	700
	Sub-total	1194	2	1192

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ANNEXURE-C (ii)

POWER DETAILS FOR MILLING TANDEM

S.No.	Name of the Installation	Total H.P.	Std.by units (in H.P.)	Under service
1.	Rake Carrier-I	30	-	30
2.	Mill drives DC Motors	2000	-	2000
3.	Lub Oil Pumps	16	8	8
4.	Rake Carriers - 3 Nos. (Intermediate)	75	-	75
5.	Hydraulic Oil Pump	15	15	-
6.	Mill Reversal Motors	100	100	-
7.	Mill Crane	46	46	-
8.	Juice Pumps	140	60	80
9.	Conveyors	27	10	17
10.	Bagasse handling Carriers	130	-	130
	Sub-total	2579	239	2340
	GRAND TOTAL (i) & (ii)	3773	241	3532

ANNEXURE-D

From HUGOT the Cane crushed (A) is given by,

$$A = 60\ ULhd / 1000$$

Where, A = Crushing rate in TCH

U = Speed of Carrier in M/min.

L = Width of Carrier in M.

h = Mean depth of the layer of cane on the Carrier in M.

d = Bulk density of cane in kg./Cum.

When the mat is filled with tangled cane, d = 150 kg./Cum. and assuming L = 1.5 m. h = 0.9 m. U = 6 m./min then,

$$A = 60 \times 6 \times 1.5 \times 0.9 \times 150 / 1000$$

$$= 72.9\ TCH$$

When the mat is filled with paralled cane d = 175 kg./Cum.

Then, $A = 60 \times 6 \times 1.5 \times 0.9 \times 175 / 1000$

$$= 85.05\ TCH$$

ANNEXURE-E

Cane Preparatory Devices - As per Standard Specification

Alternative-I:

1. Cane Kicker	40 BHP	50-70 rpm.	24 knives or 24 arms
2. Leveller	250 BHP	600 rpm.	32 knives
3. Fibrizor/Fixed hammer shredder	700 BHP	690 rpm.	44 hammers
Total power	990 BHP		

Alternative-II:

1. Cane Kicker	40 BHP	50-70 rpm.	24 knives or 24 arms
2. Leveller	250 BHP	600 rpm.	32 knives
3. Cutter	500 BHP	600 rpm.	56 knives
4. Swing hammer hammer shredder	600 BHP	1000 rpm.	144 Hammers
Total power	1140 BHP		

ANNEXURE F

COMPARISON OF POWER CONSUMED WITH PREPARATORY INDEX

&&&&&&

KW./TFH	P.I.
10	78.4
20	83.4
30	86.5
40	88.8
50	90.6
60	92.1
70	93.4
80	94.5

ANNEXURE-G

COMPARISON OF POWER FOR LPE AND CONVENTIONAL MILLING SYSTEM

*****

(in HP)

Sl.No	Equipment	LPE system	Conventional
1.	Cane Kicker	40	40
2.	Cane Carrier	50	50
3.	Cane Leveller	250	250
4.	Cane Fibrizor	800	700
5.	Rake Carrier (Cane)	30	30
6.	LPE module (8 x 30)	240	-
7.	Inter Rake Carrier	80	75
8.	Mill with UFR	500	2000
9.	Pumps (Avrg.)	180	150
10.	Bagasse Elevator	40	40
		2210	3335
	in KW.	1648	2488

ANNEXURE-H

ADVANTAGES OF LPE SYSTEM

1. Installed power in reduced by 825 KW. for rated capacity.

2. Overall Capital cost is reduced by approximately 20% combining both Civil and Machiniery cost.

3. Substantial reduction is envisaged in Maintenance costs to the tune of 60%

4. Maintenance is reduced due to absence of heavy and sophisticated equipments.

5. The equipment layout become simple and clean.

6. Automation can be easily adapted.

7. Mill roller reshelling is reduced by 75% due to the absence of heavy hydraulic loads and trash plate.

8. The performance results are as good as conventional systems.

ANNEXURE-I

SPECIFIC POWER REQUIREMENT

&&&&&&

S.No.	System	Power installed KW / TCD	Power absorbed KW / TCD
1.	Milling Tandem: Knives, Fibrizor, 4 Mill Tandem Auxiliaries	0.93	0.73
2.	Diffusor: Knives, Shredder, Two dewatering Mills, Auxiliaries	0.90	0.60
3.	LPE System: Knives, Shredder 5 LP units, MP-HP Mill, Auxiliaries	0.73	0.51

ANNEXURE-J

S.No.	Name of Items	Efficiency
1.	Primary High speed single stage gear box	0.98
2.	Double reduction helical gear box	0.985
3.	Triple reduction helical gear box	0.98
4.	Pair of spur gears (open)	0.90
5.	Pair of helical gears (open)	0.96
6.	Mill couplings (pair)	0.96
7.	Bearing Housings for open gears (single reduction)	0.95
8.	Mill crown pinions (all three)	0.95

ANNEXURE-K

COMPARISON OF DRIVE SYSTEM

*****

S. No	Particulars	Steam Turbines	Electrical Drive	Hydraulic Drives
1.	Sensitivity to Environment	No	Yes	No
2.	Characteristics:			
	Speed range	Very power	Wide	Wide
	Start stop freq.	Poor	Limit	No Limit
	Speed accuracy	Limited	Very good	Very good
	Torque Limitation	poor	Good	Very good
	E¦se of control	Difficult	Good	Good
3.	Installation			
	Wiring	Negligible	Extermine	Little
	Foundation header	Yes	Yes	No
	Alignment	Yes	Yes	No
	Adaptability to complex system	Difficult	Good	Good
4.	Performance:			
	Monitoring of power consumption	Not possible	By metering	By metering
	Overall efficiency	27% +/-1%	43% +/-1%	53% +/- 1%
5.	Maintenance & Lubrication	Heavy	Medium	Very less
6.	Space requirement	Large Area	less than steam turbines	very less

Cane crushing as per record	..	100 TCH
Cane actually crushed	..	110 TCH
Extra crushing / Hr.	..	10 TCH
Extra cane crushed for a season of 172 days	..	10 x 22 x 172 = 37840 Tonnes
In terms of crushing days	..	37840 / 110 x 22 = 15.6 days say,
No. of crushing days reduced in a season	..	15 days

ANNEXURE-M

Power Consumption of Knives
(in KW/TCH)

*****

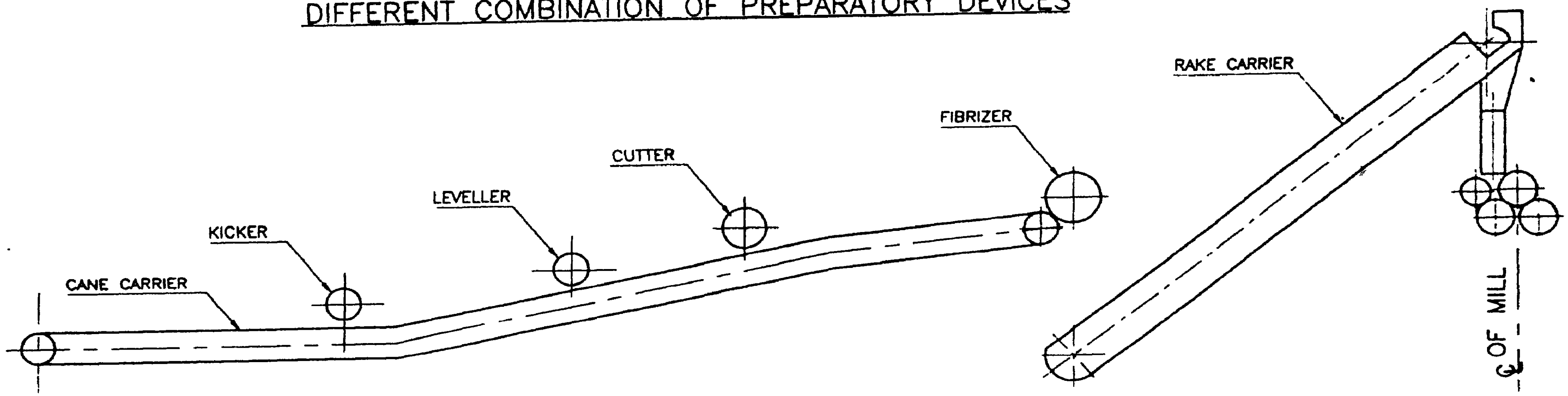
	Whole Cane			Chopped Cane		
	Pm	Pmax.	PI	Pm	Pmax.	PI
Ist set knives	0.75	3.2	1.8	0.33	0.75	0.45
II set knives	0.82	3.3	1.9	0.45	1.2	0.6

Pm. - Mean power absorbed in KW/TCH

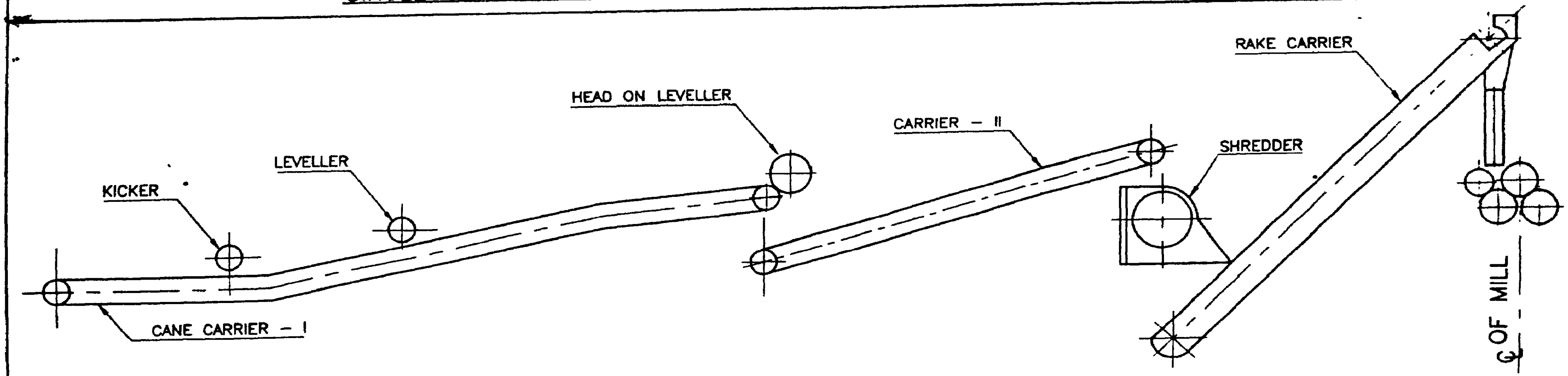
Pmax.- Max. peak power in KW/TCH

PI - Power to be installed in KW/TCH.

DIFFERENT COMBINATION OF PREPARATORY DEVICES

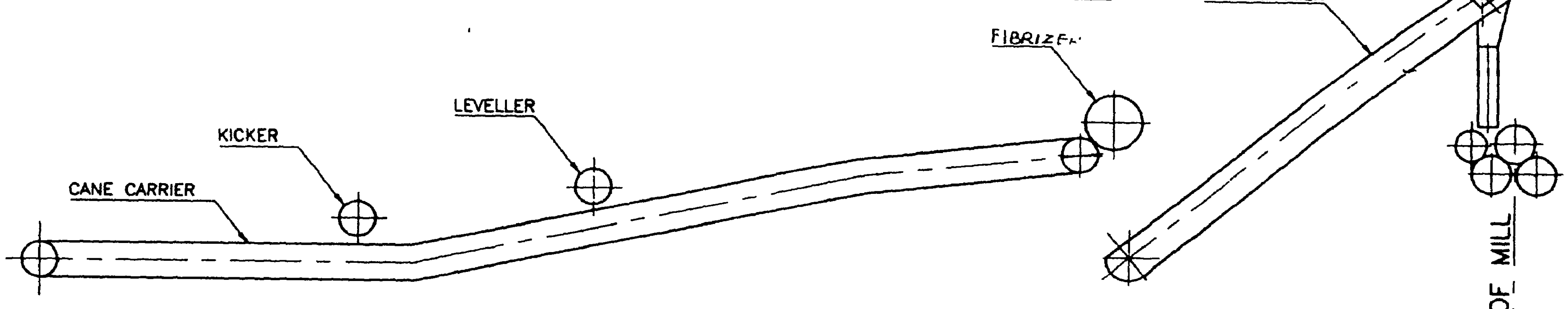


SINGLE CARRIER WITH KICKER,LEVELLER,CUTTER AND FIBRIZER.

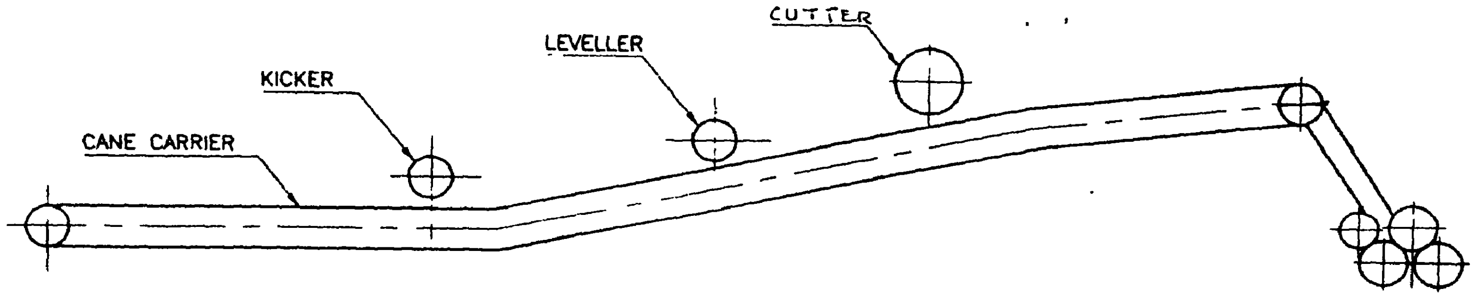


DOUBLE CARRIER WITH KICKER,LEVELLER,HEAD ON LEVELLER AND SHREDDER.

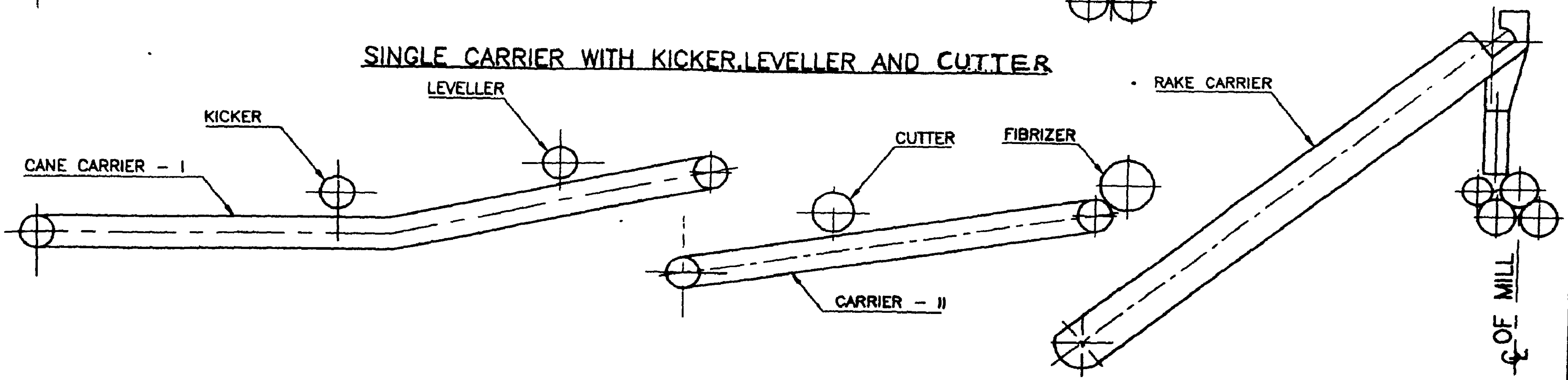
DIFFERENT COMBINATION OF PREPARATORY DEVICES



SINGLE CARRIER WITH KICKER,LEVELLER AND FIBRIZER



SINGLE CARRIER WITH KICKER,LEVELLER AND CUTTER

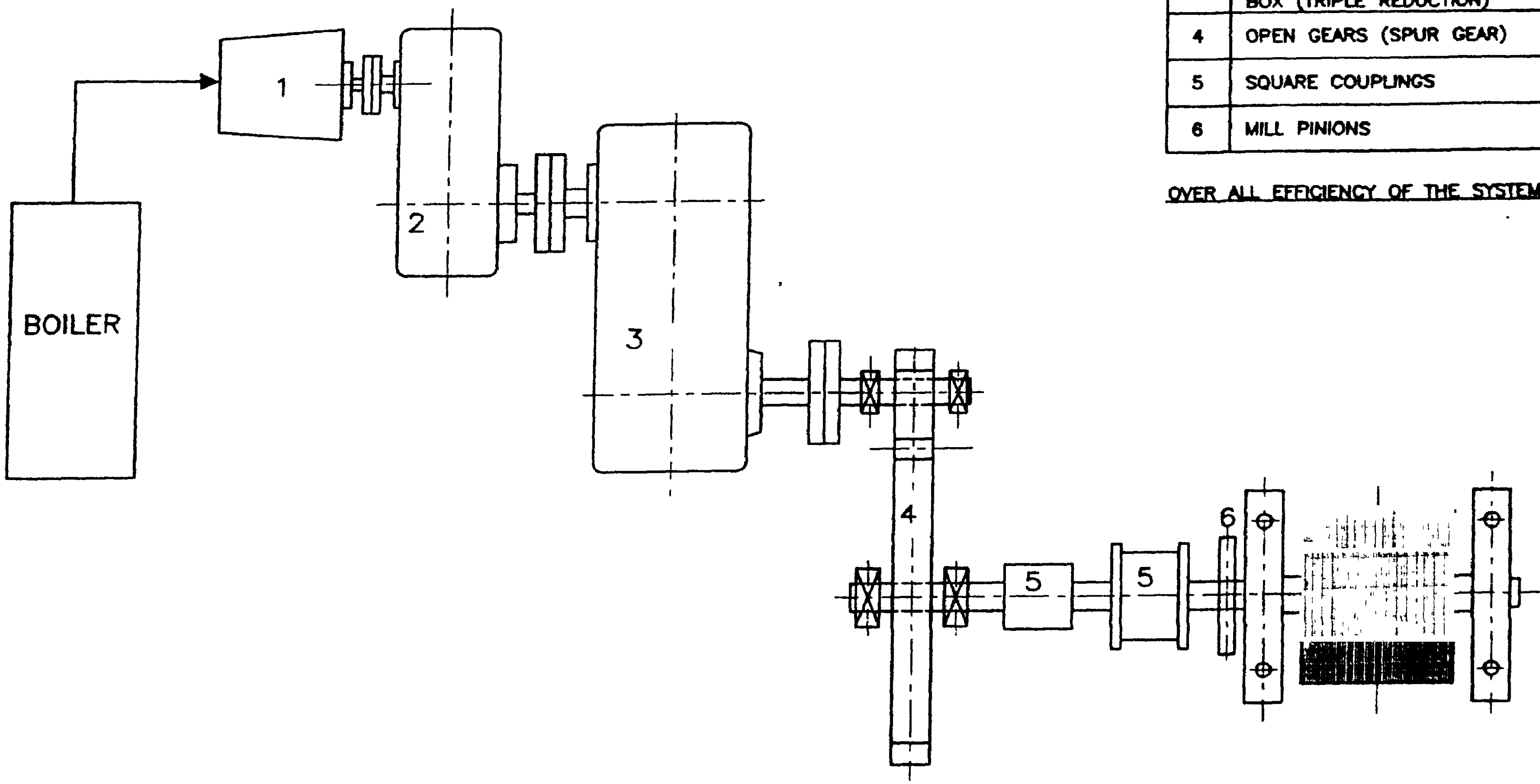


DOUBLE CARRIER WITH KICKER,LEVELLER AND CUTTER,FIBRIZER.

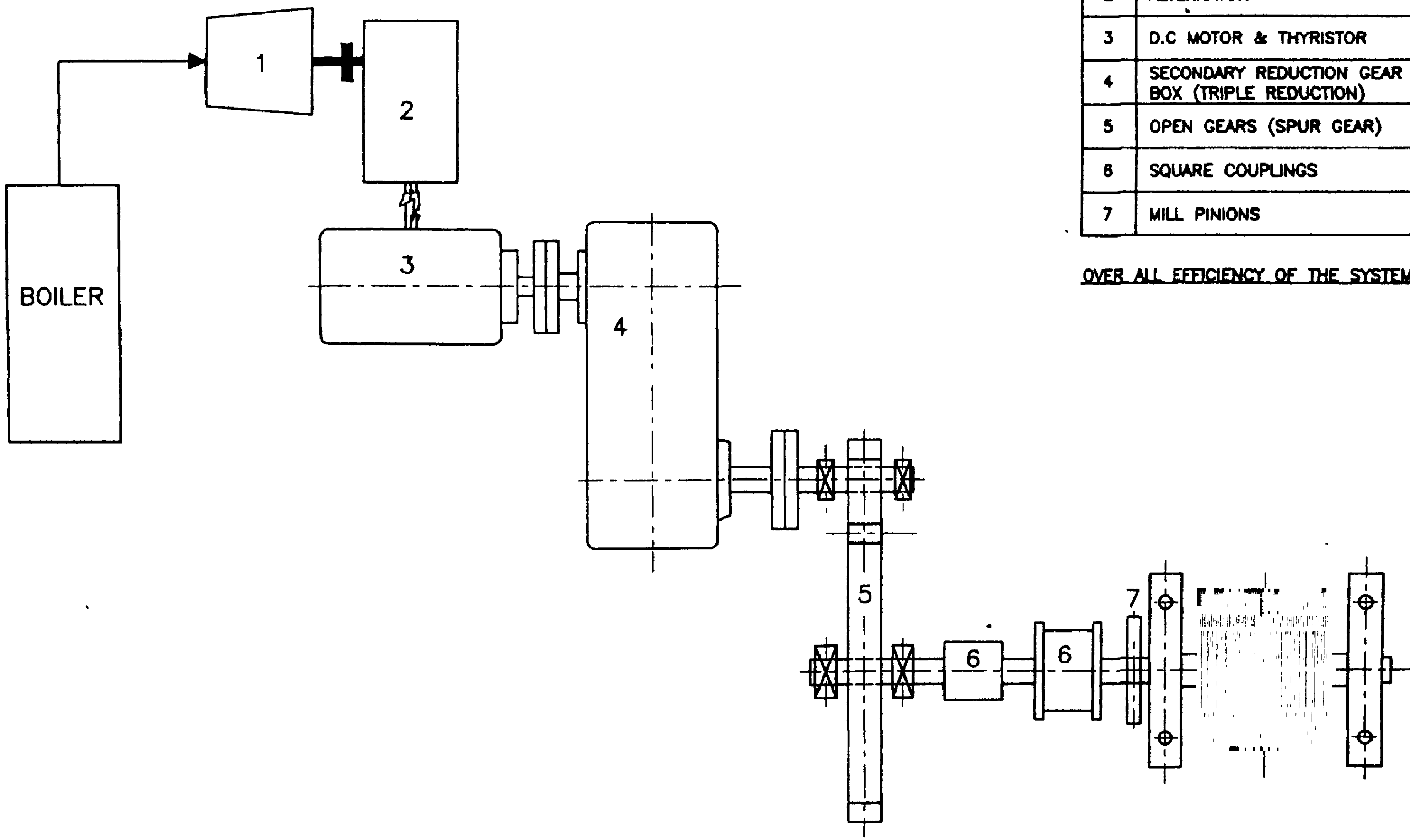
DRAWN: JK

ITEM NO.	DESCRIPTION.	EFFICIENCY
1	MILL TURBINE	40 %
2	PRIMARY REDUCTION GEAR BOX	0.98
3	SECONDARY REDUCTION GEAR BOX (TRIPLE REDUCTION)	0.98
4	OPEN GEARS (SPUR GEAR)	0.90
5	SQUARE COUPLINGS	0.95
6	MILL PINIONS	0.95

OVER ALL EFFICIENCY OF THE SYSTEM : 31.20 %



POWER TRANSMISSION BY STEAM TURBINE DRIVING THE MILL.



ITEM NO.	DESCRIPTION	EFFICIENCY
1	MULTI STAGE TURBINE AND PRIMARY GEAR BOX	0.75
2	ALTERNATOR	0.96
3	D.C MOTOR & THYRISTOR	0.90
4	SECONDARY REDUCTION GEAR BOX (TRIPLE REDUCTION)	0.98
5	OPEN GEARS (SPUR GEAR)	0.90
6	SQUARE COUPLINGS	0.95
7	MILL PINIONS	0.95

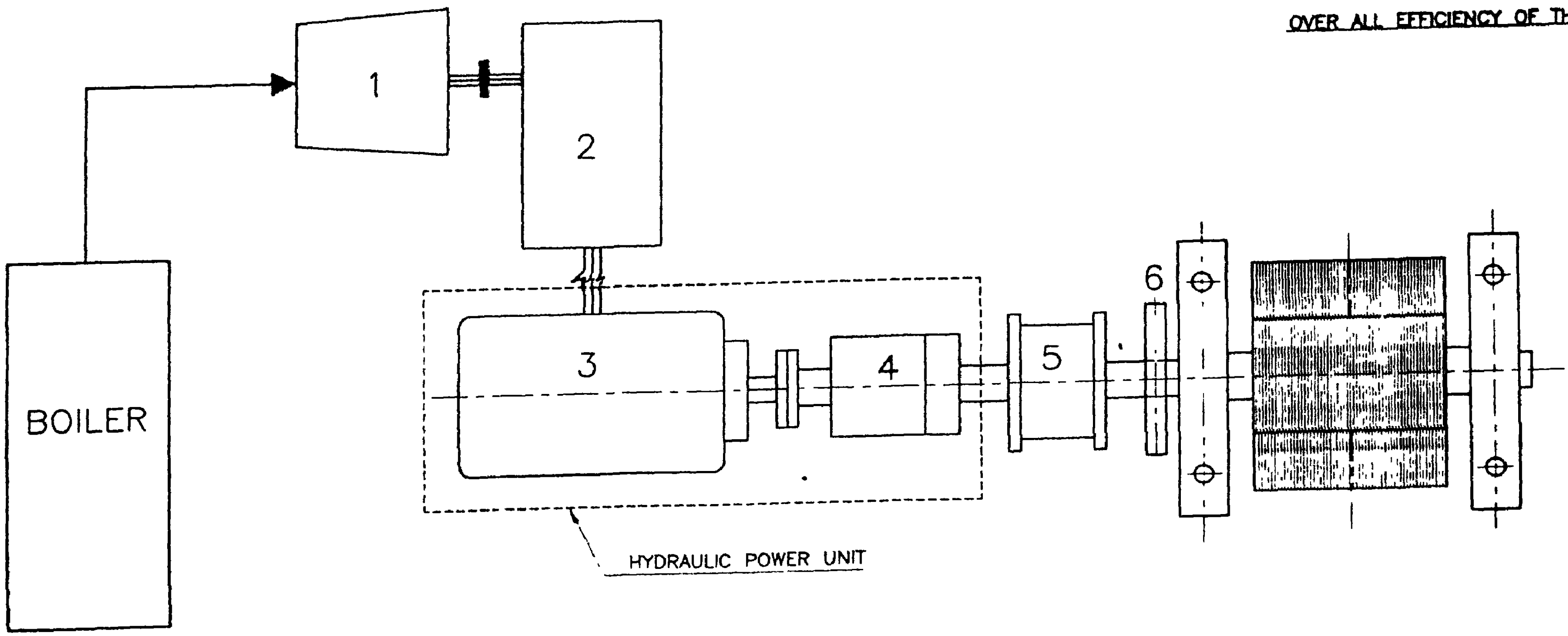
OVER ALL EFFICIENCY OF THE SYSTEM : 51.60 %

POWER TRANSMISSION BY D.C MOTOR DRIVING THE MILL.

DRAWN: JK

ITEM NO.	DESCRIPTION	EFFICIENCY
1	MULTI STAGE TURBINE AND PRIMARY GEAR BOX	0.75
2	ALTERNATOR	0.96
3	ELECTRIC MOTOR	0.95
4	HYDRAULIC PUMP	0.925
5	HYDRAULIC MOTOR	0.935
6	MILL PINIONS	0.95

OVER ALL EFFICIENCY OF THE SYSTEM : 56.20 %



POWER TRANSMISSION BY HYDRAULIC MOTOR DRIVING THE MILL.

Energy Conservation in Cane Juice Processing

Mydur Anand

ENERGY CONSERVATION IN CANE JUICE PROCESSING

By Mydur Anand

SUMMARY

Sugarcane is primarily a source of energy in many aspects. Sugar industry has the potential to produce large quantity of surplus energy. The industry has taken long strides in improving upon captive energy required for processing. Both aspects of "ENERGY" that is, Power Generation and in-house energy conservation have been explained In this presentation.

CANE SUGAR INDUSTRY-GENERAL

Cane Sugar production, has been undoubtably the world's most ancient, and still, the largest amongst FOOD PROCESSING industries, world over. SUGAR is perhaps the only processed food available in bulk, at the highest purity - above 99.8 %. India has been the originator of the sugar industry the Sanskrit word sharkara is also adopted in many languages abroad. SUGAR, ZUCKER (GERMAN), AZUCAR (SPANISH), SUCRERE (FRENCH), SHAKKAR (URDU), 3AKKARE etc., (though peculiarly as CHINI in NORTH INDIA).

India is also the largest producer of sugar, both white, crystal sugar and raw lump sugar (JAGGERY/GUR). India's production of crystal sugar in 95-96 was aver 16 million tons and in addition, about 15 million tons of JAGGERY.- These, put together, works out to a per capita consumption of over 30 kg., compared to over 45 kg. in the rich west. India has also the largest number of modern sugar processing mills, nearly 500 in numbers. Since independence, about 400 mills have been installed, almost ten per year during the last four decades. Compared to those in west, sugar mills in India are of smaller capacities - the average factory being about 2500 tons cane per day (TCD), compared to about 10000 TCD elsewhere. This is mainly because of the land holding pattern. Sugar mills in India can not, by LAW, own cane plantations, so cane has to be purchased from innumerous private farmers. There are many problems in such a system. In most other cane sugar producing countries Brazil, Australia, South Africa, Mauritius, Thailand, Cuba etc., sugar mills own and manage their own plantation.

BEET sugar is similar to cane sugar, though it is produced from BEET ROOT. This is confined to cold north countries. Beet sugar forms about 30 % of world sugar production of over, 110 million tons, the rest (70%) being cane sugar. About 15% of the world production is only involved in international trade, the rest being consumed in local areas. India has now entered the export field. When, and IF, rich nations which produce `BEET' Sugar, accept the conditions, of

WTO (GATT), etc., the potential for export of cane sugar is enormous.

1.0 SUGAR CANE & ENERGY (ENERGY CANE)

1.1Sugar Cane, a grass, primarily grown in Tropical and Subtropical zones, consists mainly of 15% sugar, 15% fibre, 5% Non-sugars and, 65% of Politics though it is all water. Ssugar, fibre etc., are all rich sources of energy; thus, sugar cane is already being called energy cane. Sugar is full of sweet calories, fibre is fuel par-excellence and 'Alcohol' energises many a moody person. Sugarcane gets all the energy by converting solar energy into available energy form of carbo-hydrates i.e., 'bio-mass'. Sugarcane is still the most efficient and cheapest form of tapping solar energy. The high fibre content enables sugar industry to be not only self sufficient in its needs of energy - Steam or Electricity. BEET has very little fibre and the industry raises its needs of steam or electricity from fossil fuels mainly fuel oil.

1.2 MILL WHITE SUGAR

India produces all its sugar directly from cane juice, using small quantities of lime and sulphur for clarification of juice etc. The product is very pure - 99.8% sucrose. The so-called refined sugar is produced by re-crystallisation after dissolving sugar Crystals. The main difference is that mill white sugar contains some calcium salts and traces of sulphur. Refined sugar is free from these.

2.0 SUGAR PROCESSING-ENERGY NEEDS

Sugar Processing is not only energy-intensive but needs energy in the forms (I) Mechanical (Electrical) to operate mills, pumps, conveyors, boiler pumps and fans etc., and (ii) Steam (at low pressure) for concentration of juice and controlled crystallisation. A 100 TCH (2400 TCD) factory needs about 45 tons of steam/hr and over 30 KWH/TC of power or 1.25 KW rate per ton cane. Though a power-guzzler industry, the saving feature is that. much more 'ENERGY' can be raised from the cane, than is needed for captive use. Depending upon the level of technology adopted, 100 tones cane/hr. can produce about 6 MW of surplus (Saleable) power. With larger mill capacities, the surplus power increases more than proportional. Thus a modern, 5000 TCD plant producing mill-white sugar can export 12-14 MW, depending upon the technology levels adopted and its management. With higher level of technology, investments are at present, disproportionally high. besides the higher risks, factor involved in managing sensitive technology.

2.1 STEAM PRODUCTION

Sugarcane in most parts of India yields a BAGASSE content of 32% on cane basis (@ 50% moisture), and 30% of it is used as fuel; this can yield 66% steam. But steam use for process has already been brought down from 55% cane to 40% cane. The steam thus saved, along with adoption

of higher operating steam pressure systems, the total power generation in a 5000 TCD plant can be around 20 MW. Allowing about 6.5MW for captive use, a 5000 TCD sugar mill should be capable of selling over 13500 units of electricity per hour or over 65 million units over a crushing period of 5000 hrs. per year. At present levels of purchase of power by SEB's, the sale of surplus power could rake in an income of over Rs. 160 per ton cane crushed, & without problems and costs of warehousing and marketability.

3.0 ENERGY CONSERVATION (CAPTIVE)

3.1 ENERGY USE PATTERN - PAST

Energy conservation - steam and power are always desirable, more so in the context of cogeneration of surplus power. The earlier generation of sugar mills primarily aimed at "SELF SUFFICIENCY" of energy and steam. Any bagasse saved was not fetching any income, often, may had to be spent on its disposal. Today every unit of energy saved is one unit sold. Hence, modern techniques of conserving energy use in sugar processing are receiving utmost attention by sugar mill management.

The earlier generation of sugar mills adopted steam pressure systems at 22 ATA, steam turbine drives for mills, electric drives for all other units. They also adopted a moderate level of multiple effect evaporation system, with low levels of vapour use. The average energy consumption was around 1 KW/TCD , plus direct steam drives for mills.

This needed exhaust steam production of 46-48% cane and this was generated and used in process at less than 2 ATA pressure. Adding the needs of steam at other pressures, at some stages of sugar processing, the steam consumption was around 55 - 58 % cane. The boilers were also equipped with moderate heat recovery systems. Consequently, the steam/bagasse ratio was around 1.8 that is, at a thermal efficiency of around 60% against 69-70 % of modern bagasse fired boilers. That meant a bagasse consumption of 32 - 33 % cane, leaving no surplus. The electric power generated was meant to supply the motive power needed by sugar mill and no surplus was neither planned nor feasible.

3.2 ENERGY USE-CURRENT

It needs to be highlighted that cogeneration power has been traditional in the sugar industry as cane is endowed with abundant fibre which makes excellent fuel. But it was for captive use only. But presently, when cogeneration is talked off it only means cogeneration of surplus power.

There is a universal attempt to conserve power and where feasible to raise it from renewable energy sources. Use of fossil fuels is to be minimised not only to help future generations but mainly to save

and safeguard ecology. Bagasse from cane is amongst the most easily renewable source of energy, hence, the stress is on cogeneration.of surplus power from sugarcane industry. To achieve maximum levels of cogeneration. of surplus power aspects, economic and efficient use of bagasse and its conversion to steam or electric power attracts much significance. But, this aspect is beyond the scope of this paper, except to mention the present status. Emphasis, now, is on energy in sugar plants.

3.3 MOTIVE POWER USE IN SUGAR MILLS

As stated earlier, cane sugar production is energy intensive. Over 40 units of electric energy (or equivalent) are required to required bag (100 Kg) sugar. This includes motive power required for milling station, Vacuum generation, centrifugal, conveying at various sections besides operation of boilers, water recirculation etc. The steam needs are around 55% ie, 55 kg/100 kg cane, now reduced to just 40 kg.

If only fossil fuels and grid power are used, the cost of energy (steam and power) would total upto Rs. 250 per 100 kg of sugar. But thanks to fibre in cane, it is, negligible now and in future there would be extra earnings from the fibre through the route of cogeneration of surplus power. The motive power needs of sugar plant which was about 1.5 KW/TCD has been brought down to less than 1.3 KW/TCD. This has been possible through more intensive cane preparation equipments. hydraulic drives for mills, force feeding drives for mills. Use of large capacity (hence less number) of pumps, centrifugal and such units. it has become feasible to reduce it to 1.25, which amounts to 6.25 MW for a 5000 TCD plant. (including mill drives).

The process steam demands have already been brought down to 40-42 % cane (against 55 %). Thanks to adoption of higher pressure systems of process steam (ie 2.5 ATA against 1.8 ATA). adoption of more efficient heat transfer equipment like falling film evaporators (FFE), continuous pans, intensive vapour bleeding, quintuple, (possibly sextuple), effect evaporators and extensive cooling of all massecuites' etc. It is already found feasible to use second effect vapours for panboiling; with FFEs and all conti pane, it should be possible to use third vapours in pans. This will bring down the steam consumption from the present 42 % to less than 38 % cane. This would help increase the quantum of surplus power for sale.

4.0 FUTURE POTENTIAL: NEW/EMERGING TECHNOLOGIES

The substantial gains already achieved in energy generation and energy use have been based largely on improved technologies and not on new technologies.

4.1. MILLING

Though `DIFFUSION' technology of juice extraction failed in India. (Two units are still, in operation), the failure was mainly due to two reasons: attempts to apply `beet-technology' to sugarcane & the difficulty of up-grading the capacity and efficiency of diffusion units, in factories which are constantly expanding their capacities, as in most developing countries. But, with improvement in technology levels all over, the diffusion technology seems to make a reentry. A pseudo combination of milling and diffusion has already made an entry into India also, though the idea originated here, over a decade ago. An Australian group also, claims to have developed this technology

4.2. PROCESSING NEW TECHNOLOGIES

The juice & syrup treatment systems presently adopted- the DOUBLE SULFITATION process - deserves replacement. Its main attraction is that it is simple & cheap way of producing `table-quality' good pure sugar. But presence of sulfur, though in traces, & well within the limits prescribed by WHO regime, is not desirable and not conductive for canning, etc. The likely new process techniques that can replace it without increasing the cost of production except marginally, are DOUBLE CARBONATION (this has its own problems, hence banned in India) and SYRUP CL-CLARIFICATION route, using the PHOSPHORIC ACID/LIME, combined with the use of coagulants & froth flotation. This does not involve dissolving of sugar purification and recrystallisation - which are essential in producing what is known as `DOUBLE REFINED SUGAR'. These steps are costly, requiring additional fuel/steam, energy, etc.

4.3 EMERGING TECHNOLOGIES

Technologies, yet to be proved, i.e., on the horizon, include ultimate filtration (micro, nano, etc.), membrane technology (reverse osmosis, etc.), or may be plain jaggery/gur, in modern jargon(organic sugar with minimum use of chemicals etc.). Already, liquid sugar, pure sugar mixed with molasses are popular in the developed world. These developments may result in less energy consumption for captive needs, thus enabling a larger power export feasible. These developments should enable production of over 125 units of electric energy per ton of cane, of which more than 80 units could be spared to the grid/other industries. Thus a 5000 TCD sugarmill should with induction of modern technology be able to spare 4 lakh units to grid daily(feed power to grid @ 15-16 MWS in the near future). This is a very substantial contribution to the power supply potential all through the quickly renewable source of energy.

ALCOHOL

This is another important by-product of great significance, in the total energy scenario, as alcohol is primarily a source of energy-particularly for many humans-in the evening hours. But its pertinence to today's situation is that its admixture with petrol will enhance its burning properties i.e. adding to its octane no. and thus eliminating the use of lead salts, presently used and which are very detrimental to ecology. Alcohol as fuel is eco-friendly. Very interestingly, the very first Government regulation, to mix alcohol in petrol, was notified in India (in old Mysore St. & old United Provinces), in the world war years. But, not any more.

RECENT INNOVATIONS FOR EFFECTIVE ENERGY EFFICIENCY IN SUGAR PRODUCTION TECHNIQUE

A. CANE PREPARATION

Intensive/ P.I = @ 90%/FBRGR Vs SHREDDER

Energy intensive but, substantial drop in energy needs later in the mills.

B. MILLING

1. Recent innovations of low Pressure Extraction.
2. Improvised Diffusion system.
3. Use of Hydraulic Drives for mills
4. Extensive arc welding of rollers
5. Use of better lubricants.
6. New drive systems-hydraulic, etc.

C. PROCESSING

- Extensive & Intensive Vapour use from later effects. Less than 3% of vapours go to condenser.
- Use of higher pressures (so temperatures) of exhaust (H.S), so capital cost and reduction in contact time (sugar juice-steam), so reduced sugar decomposition and minimum caramelisation.
- Use of falling film evaporators and
- Use of continuous pans for A, B and C.
- Effective continuous water cooling of all massecuites in water cooled crystallisers A & B in addition to C.
- Use of large sized centrifugal- adopting single curing for A and B.
- Use of only 2 injection water pumps for vacuum generation. CONTI-PANS result in lower use of condenser water, as vapour generation is steady
- Adoption of improved designs of condensers.

- Recent innovations of water cooling systems such as MIST etc.
- Efficient systems for drying and cooling of sugar in fluidised bed dryers which eliminate over heating of sugar
- Better types of sugar graders which minimise sugar recirculation.
- Adoption of bulk storage of sugar in silos /bins and automatic bagging and conveying systems.
- Large sized godowns/warehouses to minimise handling (so minimising damage and spillage) and providing good ventilation.
- With co-generation coming in, generation at higher voltage (11 KV), decentralised power distribution, ie 3/4 step-down transformers and having larger motors operating at 3.3/11 KV.
- High level of instrumentation/automation.

Present day equipments & systems, ie mills with hydraulic drives and hydraulic loading of mills rollers through a fulcrum (in FCB's new mills), centrifugal, high pressure boilers, H.T. Power generators, falling film evaporators and Contipans are by their system design, automation-friendly which makes operations smooth, continuous (minimising down time) besides being energy efficient. Automation and continuous operations greatly help in saving energy - both thermal and electrical.

Adoption of new techniques like energy audit thus necessitates developing bench-marks for energy consumption at different production stages and then checking, reviewing and improving the actual performance. Presently most Energy Audit reports are more energy advise reports.

TARGETS

PRESENT	STEAM (% CANE)	ENERGY (KWH/l t/cane)
Old units	58%	1 KW/TC + 120 steam at 310°C
New normal	50%	1 KW/TC+100 kg steam)
Good	42%	1.35 KWh /TCD incldg. Mill Drives
Future	38 %	1.25 KW/TCD including Mill Drives

CO-GENERATION OF SURPLUS POWER

2500 TCD/PLANT; 32% Bagasse (30% as fuel):
115 TCH/35 t/h bgss/75 t/h steam)

Boiler: 46 ATA/ 420 degree centigrade
Process Stm needs: 40 % 0 2.t + 2 % @ 7.0 ATA
i.e. 48 Tons / Hr.
Steam Available = 115 x 0.3 x 2.35 = 81 Tons/Hr.
Power from Prcs stm (@7.8 kg/KW = 48/7.9 = 6.15 MW
Surplus stm (Condensing TG set) = 81-48/4.8 6.85 MW
Total power generation 13.00 MW
Power for captive needs 3.75 MW/ m 4.00 MW
Surplus power from 115 TCH = 13-4 = 9 MW

For 1 ton cane = 78 units
@ Rs. 2.60/KWH, Rs 202/ T Cane(and Rs. 10 crores per five lakh tones season)

May sugar cane be hereafter, known as Energy Cane & provide the energy needs of human being human societies.

Membrane Technology—Applications and Prospects in Sugar Industry

Malini Balakrishnan
TERI

Membrane Technology : applications and prospects in the sugar industry

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1. Background

India is one of the major sugarcane cultivators in the world with an output of around 276 million tons in the year 1995-96. A substantial proportion of this cane (almost 60%) is utilized for the production of sugar, with the rest being diverted for the preparation of gur/khandsari as well as for consumption as seed and feed. As the sugar manufacturing process is characterized by high energy consumption (typically 50-70% steam on cane), there is an urgent need to explore less energy intensive alternatives. One such possibility is to employ simple, clean and energy efficient technologies like membrane separations which can be easily retrofitted into the existing scheme for sugar manufacture.

Membrane separations technology is characterized by several advantages. The process is based on the ability of the membrane to act as a selective barrier which leads to the physical separation of the chosen components from the feed stream without the addition of any extraneous chemicals. It is thus a clean, environmental friendly technology which avoids the generation of supplementary waste streams and their subsequent disposal. Continuous operation is possible and large throughput can be obtained by choosing the appropriate membrane and module configuration. The system is easy to install and scale-up due to the modular nature of membrane units and can be accommodated in a limited space. No complicated heat transfer or heat generation equipment is needed since membrane operation requires only electrical energy to run the pump motor. The maintenance requirement is also minimal due to absence of moving parts. Lastly, membrane systems can be readily integrated with other conventional unit operations thus leading to successful "hybrid processing".

2. Potential membrane applications

The manufacture of plantation white sugar from cane broadly involves the following steps :

- Extraction of juice from the raw cane by crushing in a milling station employing a tandem of 3-5 mills; weak juice and makeup water are added in successive stages to maximize the juice recovery from the disintegrated cane in a counter current leaching system ("imbibition")
- Purification of the raw juice which involves liming and sulphitation followed by heating to precipitate out the impurities; the sludge formed is subsequently separated

in a clarifier, with the purified juice being withdrawn from the top while the muddy solution at the bottom is further filtered in vacuum filters to recover the remaining juice

- Concentration of the clarified juice in multiple effect evaporators
- Crystallization ("pan boiling"), usually carried out in batch type vacuum pans and
- Centrifuging, drying and packing the sugar crystals.

Figure 1 indicates possible membrane applications at each stage of the sugar manufacturing process. The cane juice clarification can be accomplished by microfiltration(MF) and/or ultrafiltration (UF). The purified juice can undergo deashing by either nanofiltration (NF) or electrodialysis (ED). Partial dewatering of the purified juice (up to 40 Bx) can be accomplished either by NF or by reverse osmosis (RO) before concentrating to 60 Bx by evaporation. Yet another application is the decolorization of the concentrated syrup by MF / UF prior to crystallization. Finally, desugarization of the molasses by ED, after appropriate dilution of the feed, would help in recovering the sugar, albeit in a dilute solution. Also, the potassium enriched concentrate from this process could be a valuable fertilizer.

There are several benefits associated with membrane separations in sugar manufacture.

1. Purification of cane juice by MF and/or UF leads to a higher clear juice purity as compared to that obtained by the traditional liming and sulphitation process. The sugar loss in the molasses is thus lower resulting in higher sugar recovery.
2. Cane juice clarified by MF/UF is sparkling clear and is characterized by lower colour as compared to the conventional clear juice. This would directly translate into improved sugar quality.
3. In view of the better clear juice produced by MF/UF, the consumption of chemicals at the clarification stage would be substantially reduced. It is, in fact, possible to completely eliminate the use of sulphur-di-oxide at this stage which could significantly lower the sulphur content of the sugar.
4. Purification by UF alone or in combination with NF/ ED for deashing the cane juice prior to concentration, would aid in controlling the evaporator fouling. This, in turn, would mean less frequent shut-downs for cleaning and reduced consumption of cleaning chemicals.
5. Since membrane processes are typically characterized by lower energy requirements as compared to conventional dewatering processes like evaporation, substantial savings in energy are possible by employing this technology. The energy consumption in membrane processes (MF / UF / NF / RO / ED) is in the 1-20 kWh/m^3 range which compares very favourably with that for evaporation(628 kWh/m^3). In addition, reduced evaporator load implies increased evaporator capacity as well.

The aim of this presentation is to introduce membrane separation processes which are relevant to the cane sugar industry. In addition, the current status and future prospects of this technology would also be touched upon.

3. Basics of membrane separation

3.1 The process

Membrane separation processes are based on the ability of semipermeable membranes to distinguish between molecules primarily on the basis of size, and to a lesser extent, shape and chemical composition. The physical characteristics (primarily the pore size and pore size distribution) as well as the chemical nature of the membrane controls the capability of the membrane to retain the desired component(s). The driving force for the separation is either pressure (as in the case of MF / UF / NF/ RO) or voltage (as in ED). Figure 2 depicts the pressure driven membrane processes. Starting from MF which operates at pressures of up to 1 bar and retains particulates/suspensions, the membranes become progressively "tighter". Thus RO, with pressures typically in the 20-50 bar range, allows only water to pass through.

3.2 Membranes and modules

The heart of the membrane process is the membrane itself. Membrane materials can be broadly divided into two categories viz. organic and inorganic. Organic membranes are based on synthetic polymers (such as cellulose and its derivatives, polysulphone, polyamide etc.) while inorganic membranes comprise those made of ceramics, glass, carbon etc. Regardless of the membrane material, a prime concern in food processing applications relates to the "biocompatibility" of the membrane /module system. This involves issues like :

- stability to extremes of pH and temperature, especially under cleaning and sanitizing conditions
- minimizing membrane-feed interactions which would affect the extent of membrane fouling and hence the cleaning frequency, rejection of individual feed components and the product yield
- acceptability of the membrane as a food contact material, essentially implying that the membrane material be inert and not leach out into the processing stream.

Both organic and inorganic membranes have been investigated in the processing of cane juice and syrup. Owing to their better operating stability at high temperatures / pH, combined with longer life, inorganic membranes are favoured to some extent. However, the high cost (typically ten times more than organic membranes) is often a deterrent especially in this application which involves large feed volumes and consequently large filtration area.

Membranes are commercially available in four different module configurations i.e. spiral wound, plate and frame, hollow fiber and tubular systems (fig 3.). Table 1 presents a comparison of different membrane equipment. The final choice of the membrane module is dictated by considerations like the properties of the feed stream (loading of suspended particles, particle size, solution viscosity, fouling potential), energy consumption as well as the capital and membrane replacement cost. The lowest cost and energy consumption is provided by spirals; however, as they have limited capability to handle particulate matter, prefiltration of the feed is often mandatory. On the other hand, tubular systems can handle large amounts of suspended matter but are characterized by high module costs combined with the highest energy consumption of all designs.

Table 1 - Features of membrane equipment

	Tubular	Hollow Fibers	Plates	Spiral
Channel height (mm)	> 10	< 3	< 2.5	< 1.5
Spacers	No	No	Yes/No	Yes
Prefiltration	No	Yes	Yes/No	Yes
Flow	Turbulent	Laminar	Laminar	Turbulent
Flux	High	Intermediate	Intermediate	Low
Area/Volume	Low	High	Intermediate	High
Energy/Flux	High	Intermediate	Intermediate	Low
Cost ($/m^2)	100-150	200-300	100-150	30-120

4. Membrane applications in cane sugar industry

4.1 Current status

Systematic investigations on the application of membrane separations for both cane and beet sugar manufacture were initiated in 1971 by the Danish sugar industries (De Danske Sukkerfabrikker; DDS). The earlier experiments on the clarification of limed juice were performed with cellulose acetate membranes but the capacities obtained were unacceptably low. However, rapid progress in membrane technology combined with the development of new membrane materials like polysulphone revived the interest in this separation method in the eighties. Yet steps towards possible large scale applications have been taken up only in this decade. In 1990, Pak Sap sugar mills conducted semi-work scale trials on the clarification of mixed cane juice by membrane filtration. Spiral wound modules were employed to produce

10m³/h of sparkling juice from which near white sugar was produced in a single crystallization step. MF of mixed juice has also been adopted by Honiron Engineering, USA who have developed the A.B.C. process for the direct production of refined sugar. The mixed juice is microfiltered through hollow fiber membrane modules, following which color removal is accomplished by adsorption on a macroporous polymer structure. Full scale operation was scheduled to begin in a US cane sugar factory in early 1997. No further details are available. The only known commercial application of ultrafiltration for cane juice clarification was reported by the Hawaiian Commercial and Sugar Co. (HC&S) . In this process (termed the New Applexion Process N.A.P), clarified juice at 95 °C was screened through a mesh before passing through a ceramic Kerasep membrane system (TechSep, France) with a total filtration area of 940 m^2. This was followed by juice softening using ion exchange resins. Colour reduction of over 40% was observed in the sugar produced from the ultrafiltered juice. The unit has been in operation since September 1994.

On the national level, though several workers have addressed the issue of incorporating membrane filtration in the Indian sugar industry, the investigations have largely been confined to laboratory experiments or bench scale trials in the industry. The use of reverse osmosis has been advocated, primarily from the viewpoint of energy conservation, both for the concentration of secondary (thin) juice as well as the mixed juice prior to evaporation. The purification of raw juice by ultrafiltration has also been contemplated and bench scale investigations (essentially for turbidity reduction) have been reported with hollow fiber modules. Preliminary trials have also been performed on the demineralization of clarified juice by electrodialysis. On a pilot scale, a 10TPH demonstration plant using membrane filtration is scheduled to be commissioned in 1998 as part of a project implemented by TERI (sponsored by the Sugar Technology Mission, Govt. of India). This should provide the necessary impetus for possible commercialization of this technology.

4.2 Future prospects

Due to the inherent nature of sugar manufacture, applications in this sector impose specific requirements on the membrane system characteristics.

1. The membranes should provide high flux (flow rate per unit membrane area) as the juice volumes to be handled are very large (typically 100-400 m^3/h).
2. High temperature operation(60- 102°C) should be possible since juice processing is preferred at these temperatures to avoid microbial contamination. Besides, high temperatures reduce feed viscosity, thus making pumping easier. In addition fluxes are also higher at higher temperatures (for instance, in the UF of cane juice, fluxes are almost double at 60°C as compared to that at 30°C).

3. The module should be capable of handling small amounts of abrasive materials (grit, sand etc.). This is especially required while processing mixed/raw juice streams without rigorous pretreatment.
4. High concentration factors are desired (especially in juice purification), to minimize sugar loss in the retentate.
5. The membrane system should be mechanically stable to withstand continuous operation for the season while maintaining acceptably high fluxes and separation characteristics.

At present, a variety of membrane systems are commercially available in the Indian market. Laboratory investigations indicate that membrane operations for purification, deashing, decolorization and dewatering of cane juice are technically feasible and appear very attractive from the viewpoint of excellent clear juice quality. Thus, at this juncture, it is critical to perform pilot scale tests over a complete season to evaluate the long term process characteristics and system reliability. The process economics would also become clear at that stage. It is felt that the cooperative efforts of membrane manufacturers, end users and government agencies would be of primary importance for the eventual acceptance of this technology by the sugar industry.

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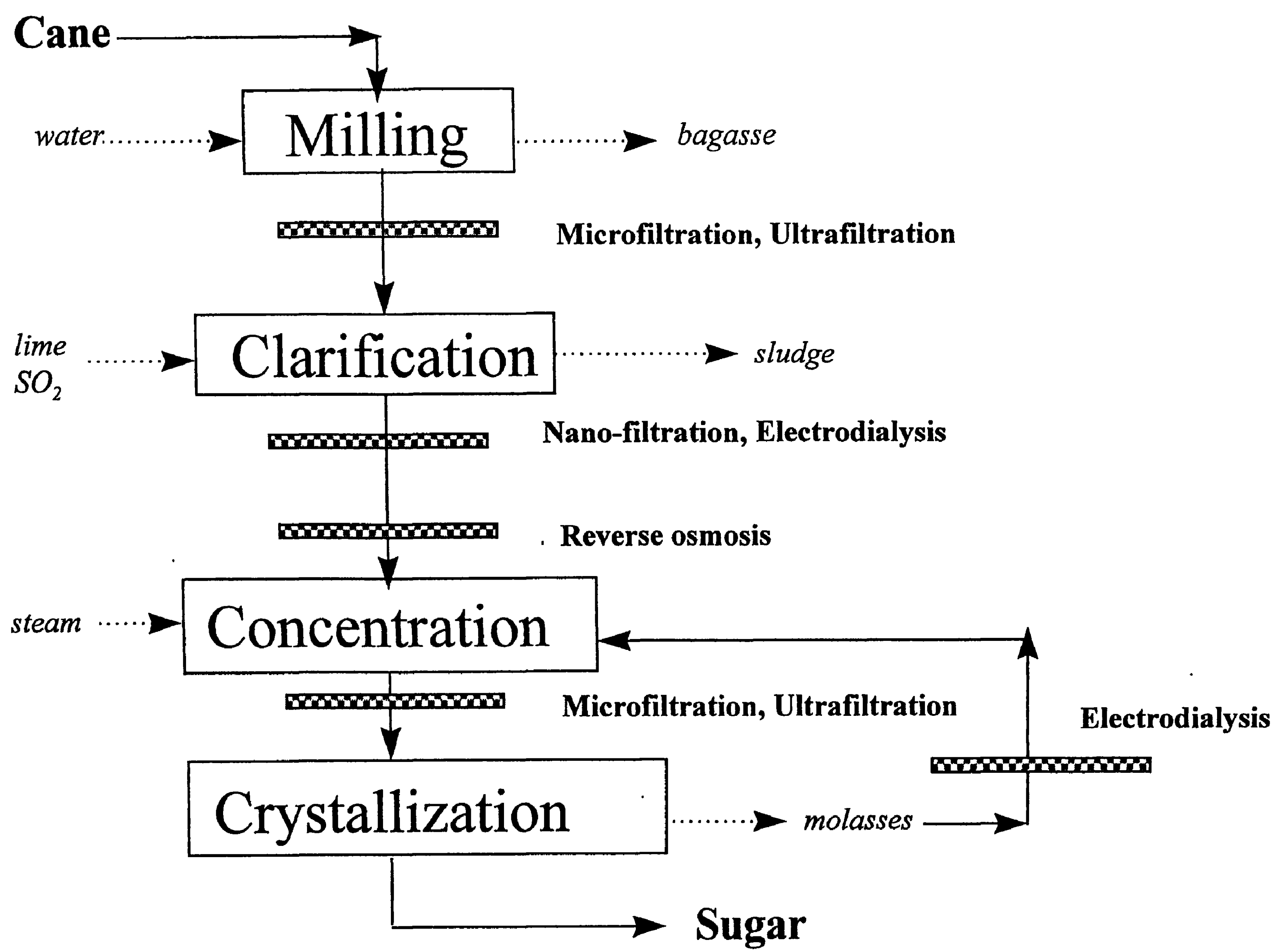


Fig 1: Potential membrane applications in the sugar industry

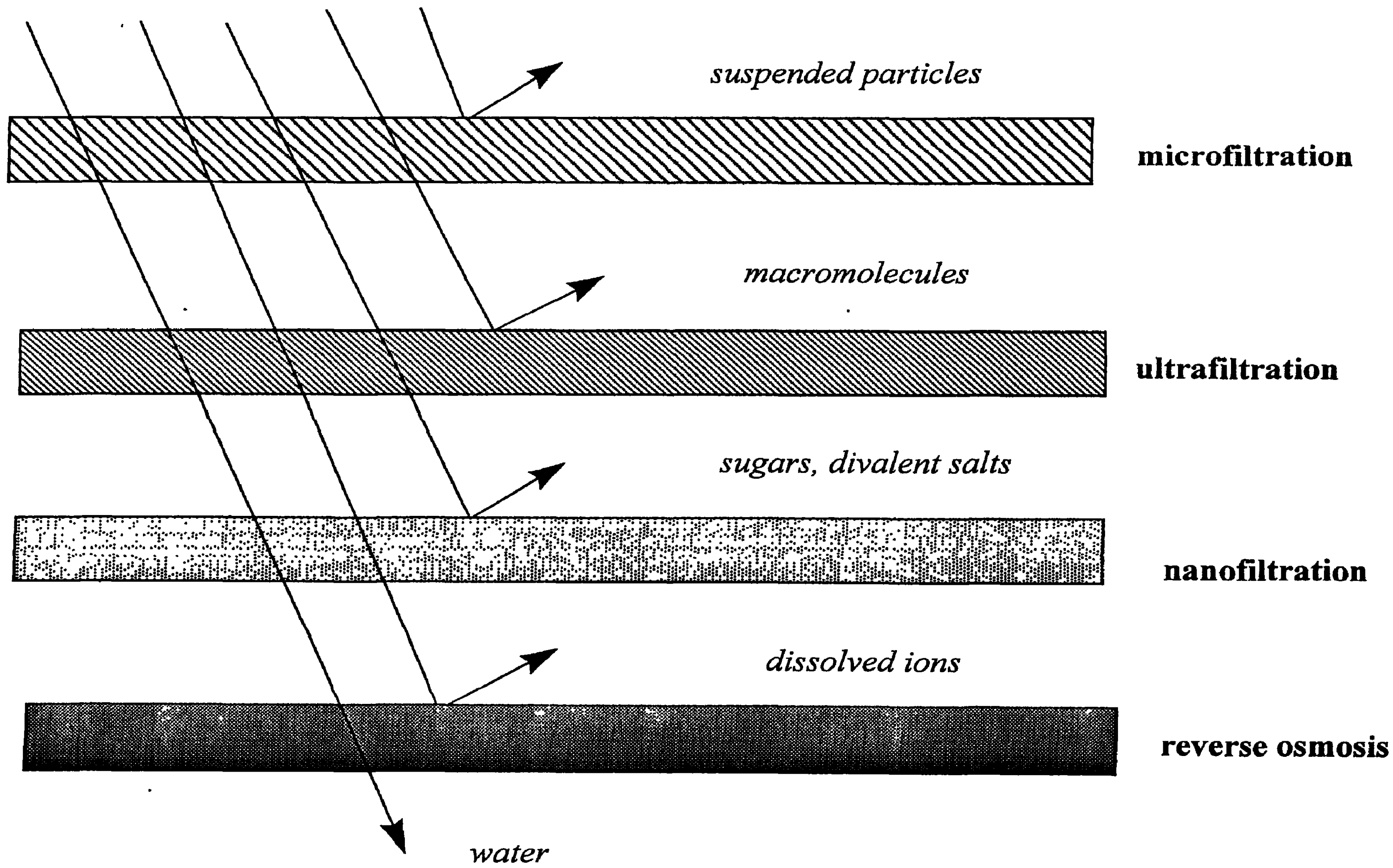
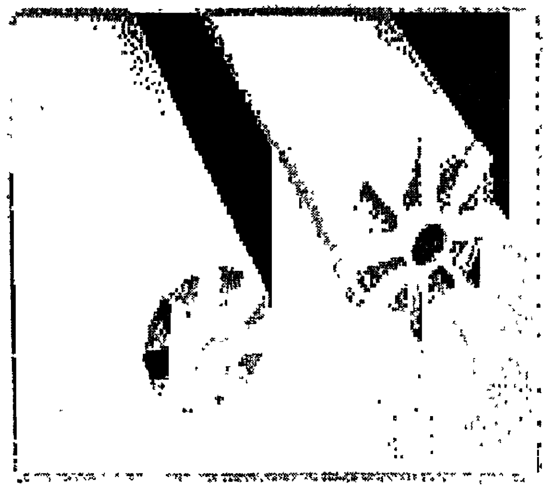


Fig 2: Schematic of pressure driven membrane separation processes



Spiral wound

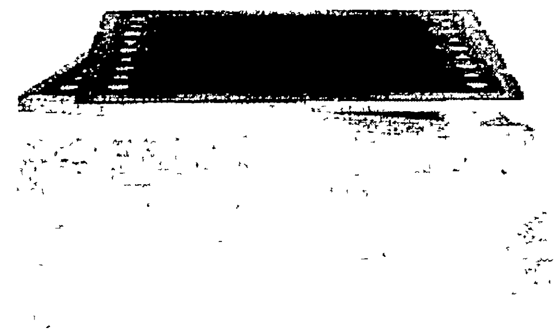
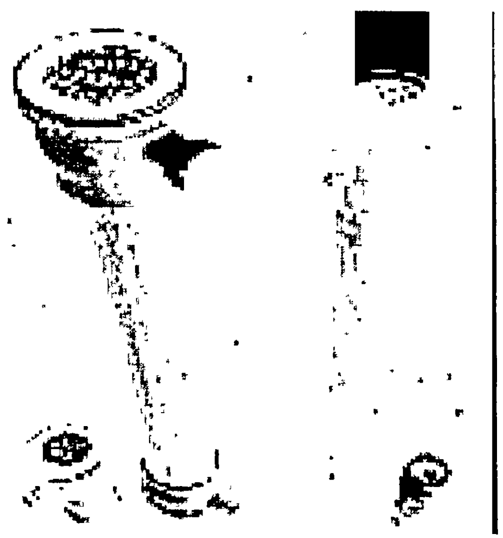
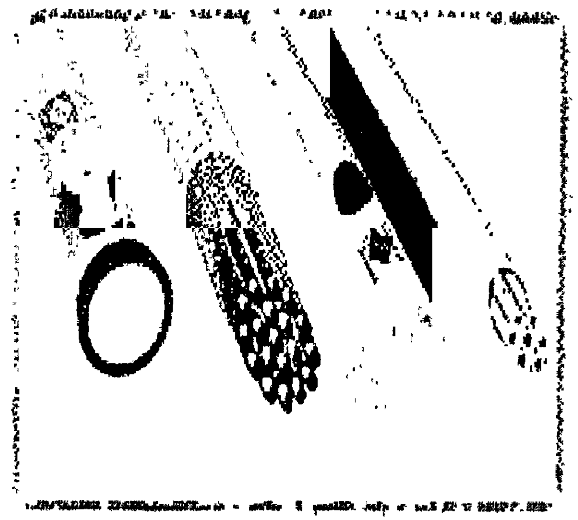


Plate & Frame



Hollow fiber



Tubular

Fig 3: Commercial membrane modules

Environment Norms and Pollution Abatement Measures in Sugar Industry

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ENVIRONMENT NORMS AND POLLUTION ABATEMENT MEASURES IN SUGAR INDUSTRY

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ABSTRACT

The sugar & allied industry is considered to be more polluted one, although sugar factories are much less polluted than alcohol, leather & paper industry, these effluents, however, if left to stagnate for long, cause water & air pollution due to obnoxious smell caused by anaerobic decomposition. Such effluents may also affect the soil structure & crop productivity, if disposed on land for very long time their impact on the environment as a whole may possibly affect the human & animal health in the long run, but so far no authentic report to this effect is available.

The conventional treatment technologies available for control of water pollution in sugar & allied industry include both anaerobic, semi-aerobic & aerobic systems preceeded by primary treatment Several anaerobic treatment systems have been tried like anaerobic contact filter, anaerobic rotating biological contactors, biomethanation processes such as upflaw anaerobic sludge blanket reactor, fluidised bed reactor, biothane & biobed processes, etc. The anaerobically digested effluent may be treated further either by oxidation ponds, oxidation ditches, trickling filters or by aerated lagoons using activated sludge or extended aeration process. Some factories have also used water hyacinth cultivation & algal ponds but disposal of vast quantity of biomass has been a problem Similarly bioearth process and earthworm based trickling filters have also been tried with some success.

The recently developed membrane filtration, microfiltration, nanofiltration & reverse osmosis processes are not yet known to be tried in India due to very high costs of membrane systems. Some factories have adopted Spranihilator/ Spranitherm & similar processes of effluent concentration & incineration for achieving 'Zero Pollution' in alcohol industry. On the other hand, some Karnataka State factories have resorted to the practice of water conservation & recycling of hot & cold waste streams in order to achieve this goal.

The air pollution in sugar & allied industry is mainly significant with respect to suspended particulate matter in the flue gases. Multiclones & fly ash collectors have been the preferred choice to a large number of factories, although some factories have installed water scrubbers also, with little success. The use of bag filters & ESP's in sugar industry is not yet known possibly due to their high costs

An overall view of various treatment technologies has been presented.

WATER POLLUTION

The sugar industry effluents contain only sugar, oil/grease, bagasse particles & a little pressmud as suspended matter There is apparently no toxic or hazardous pollutant The combined effluent is pale yellow, turbid, and has a sweet smell. The characteristics of the effluent vary greatly from mill to mill and time to time & depend on water usage practices & process conditions.

The average composition of combined effluent is :

BOD	900 to 1500	Av 1000 mg/l
COD	1700 to 3000	Av 2200 mg/l
Oil/Grease	10 to 60	Av. 30 mg/l
Total Dissolved Solids	300 to 1900	Av. 1500 mg/l
Suspended Solids	30 to 600	Av. 250 mg./l
pH	4.6 to 7.1	Av. 6.3

The average water consumption is 0.14 to 1.4 cu meter per ton of cane crushed and the average water discharge is 0.16 to 0.76 cu meter per ton cane crushed. The average waste water generated from sugar mills of different crushing capacities is :

Crushing Capacity	*Waste Water Generated*
Upto 1250 TCD	200 to 600 KLD
1250 to 2500 TCD	450 to 900 KLD
2500 to 5000 TCD	700 to 1550 KLD
Above 5000 TCD	1300 to 2500 KLD

A number of treatment technologies are in use for control of water pollution

Treatment Technologies :

1) **Primary Treatment :**

Screening - Coarse & fine screens.
Filtration and Diffused Air Floatation
Settling tanks and Clarifiers - Primary/Secondary Equalisation · lime neutralisation cum preaeration.

2) **Secondary Treatment :**

a) Anaerobic : These systems can accept high less nutrients, produce little biomass sludge, do not depend on oxygen transfer & can produce some useful byproduct like methane, and the active anaerobic biomass can be kept for a long time without feeding.

(I) Ammonifying bacteria process :

Employs a specially developed strain of bacteria for treatment of spent wash under anaerobic conditions. The process is free from foul smell

(II) Biomethanation processes :

Methanogenesis is a microbiological phenonmenon associated with breakdown of complex organic matters into methane, carbondioxide & water, in absence of oxygen, with intermediates like acetate, propionate, butyrate, isobutyrate, valerate, isovalerate, hydrogen & carbondioxide.

(i) Mobilised Cell Processes :

In this process, bacterial cells are in suspension & are completely mixed within the reactor by artificial means. The SRT/HRT ratio of 1 to 10 can be achieved. The different processes are : Conventional digestor & Anaerobic activated sludge

(ii) *Immobilised Cell Processes :*

In this process, the bacteria are concentrated within the reactor by attaching themselves to an inert supporting media or by way of attaching themselves together to form flocs which settle rapidly.

(1) *Fixed Medium System :*

The bacterial attachement medium is stationary & liquid flow regime is by plug flow The examples are -

Anaerobic Contact Filter (AF)
Downflow Stationary Fixed Film Reactor (DSFF)

(2) *Completely Mixed Fixed Film System :*

The bacterial attachment medium and the liquid regime are uniform throughout the system. The examples :

Anaerobic Rotating Biological Contractors (AnRBC)
Anaerobic Attached Film Expanded Bed Reactor (AAFEB)

(3) *Fluidised Bed System :*

Fluidisation offers mixing of medium uniformly within the reactor when little or no recycle is required for fluidisation. The liquid follows a plug flow pattern while biofilm approaches completely mixed state. The following reactors fall into this group :

Upflow Anaerobic Sludge Blanket Reactor (USAB)
Anaerobic Baffled Reactor (ABR)

Improved digestion systems incorporate advanced reactor designs & fermentation modes that result in the operation of the process at lower HRT's and higher organic loading rates than are possible with the conventional high rate single stage digestors. Achievements of these objectives means reduction in capital & operating costs & enhanced net energy (surplus methane) production

(4) *Miscellaneous Systems :*

(a) *Upflow Blanket Filter (UBF) :*

This is a hybrid reactor made by coursining [Combining] an Upflow anaerobic Sludge Blanket (USAB) & an Anaerobic Filter (AF). Plastic ring floating in the top third of the reacor comprises anaerobic filter while the bottom two-third volume is occupied by USAB system.

(b) *Anfil Digestor :*

This process enables the methane generation from low BOD wastes like that of sugar industry, which pass through regions of high methanogenic activity, where waste digestion takes place.

The Anfil digestor (Anaerobically filled digestor) has very low detention period & occupies less land, the power consumpotion is very less, the retention period is 9 hrs only & in this process carbondioxide is scrubbed out

Biomethanation plants designed by :

K.C.P. Ltd., Vyyuru
Sulzer's 'On-Opur'
SGN France Technology of Sakthi Sugars ~~Bacardi, USA~~
Bacardi, USA
Degremont's process
Western Pacques System
Dorr Oliver's Biphasic System
Bulk Volume Fermentaion Process of M/s Utility Equipments Ltd.
Others.

(b) ***Semi - Aerobic :-*** These processes are "in-between" and can be used to treat the effluents (after anaerobic treatment) under partial aerobic conditions. These are less expensive to run but involve more recycling or land area

(1) ***Rotating Biological Filters (RBF) or Rotating Biological Contactors (RBC) :***

They resemble the trickling filter process in that they use a biological film grown on solid surfaces. A large number of fixed spaced discs mounted on a single shaft rotates above a shallow basin profiled to the perimeter of the discs. About 40% of surface of each disc is submerged in waste stream flowing through the trough at any time. The shaft slowly rotates, alternately exposing the biological growth on the discs to atmosphere & submerging it in the flow. During the period of the contact with waste stream, the biological film absorbs organic matter & then during contact with atmosphere it absorbs oxygen, so enabling aerobic oxidation to proceed. The net growth of biomass is washed off the surfaces of the discs & may either be discharged (&) settled depending on application.

The principal benefits of RBF system are simplicity of operation & low power consumption while major drawback is the lack of speed control.

(2) Oxidation ponds/ditches
(3) Trickling filters or biofilters
(4) Algal ponds
(5) Water hyacinth ponds
(6) Golden fish culture of Vorion Distillery
(7) Wetlands

(c) *Aerobic* :- They are more efficient to reduce the pollution loads, take less time and are free from foul smells but involve high capital & operational costs and pose sludge disposal problem. They employ forced aeration either by stirrers or by compressed air for rapid oxidation of pollutating matter.

(1) Activated sludge process
(2) Extended aeration process by -

a) Compressed air supply
b) Surface aerators - Fixed / Floating

(3) *Electrochemical oxidation.*

(d) *Miscellaneous Processes :*

(1) *Bioearth Composting System :-* Composting is a biological process in which the organic matter is degraded under controlled conditions. Under the process developed by M/s Fabcon of Phillipines, the concentrated spent wash is filled in the windrows/trenches & is saturated into boiler ash/pressmud alongwith a starter microbial culture 'FABEARTH-MICRO-118' over a period of time. The whole mass is digested into a compost under aerobic conditions with the help of AEROTILLER, used to aerate & turn & dry A distinctive black, loamy, free flowing & baggable compost with pleasant earthy smell 7 - 35% moisture content is produced.

(2) *BV Process of Using Earthworm Bioreactors :-* Earthworms have various degradative enzymes like protease, lipase, amylase, cellulase, lichenase, chitinase, etc. and hence can be used to biodegrade complex biopolymers present in effluents. In this process developed by Bhawalkar Institute, Pune a Vermifilter is used. It is a packed tower consisting of active biomass of earthworms & vermicastings (their excreta). Primary, secondary & tertiary treatments take place in the same unit. Pretreated spent wash is sprayed from top. The spentwash trickles down the highly absorbant mass of vermicastings & treated water comes out at bottom. Organic impurities & plant nutrients are absorbed on vermicastings present inside. They are regenerated by earthworms, which produce more absorbant medium (vermicastings). There is simultaneous production of earthworm biomass. Surplus vermicastings & earthworm biomass are removed from the top periodically & sent as manure.

(3) Others.

(e) *Zero Pollution Systems :*

(1) *Drying, Concentration & Incineration Process :*

(i) In some processes, the effluent is concentrated to 60 degree Brix, mix spent grains, bran & other nutrients & use as cattle feed.

(ii) In other technologies, the concentrated effluent is mixed with bagasse or other fibrous agriculture waste & burnt in a furnace to raise steam. NPK rich ash is used as fertilizer.

(iii) Drying, concentration, incineration & energy generation (DIEG) process of VSI, Pune.

(iv) The effluent may be concentrated into a dry biomass by spray drying; however, no such attempt is known to be made.

(v) Sprannihilator/Sprannitherm process

(II) Water Recycle & conservation Practices - Karnataka State Sugar Factories.

(3) Teritary Treatment :

As a clarification aid, sometimes flocculants like alum, lime, polyelectrolytes, etc. are added to the treated effluent in order to precipitate out the fine suspended & colloidal matter & to obtain a clear effluent The treated water may be then finally treated with chlorine, ozone, UV-light, etc. in order to disinfect the same and to make it free from pathogenic bacteria.

Recently some new techniques based on microfiltration have been devised to remove all suspended solids, bacteria & viruses, etc Memtec Ltd , Australia have provided microfiltration technology to remove oil, mercury, copper sulphate, asbestos, BOD removal and for concentration of high MW proteins from food, dairy and tannery wastes Its Reverse Osmosis membranes have been used for desalination of salt water Memtec's crossflow microfiltration system has improved overall efficiency of microfiltration by another 300% A compressed gas is used instead of a liquid to effect membrane cleaning on a regular basis.

All the membrane processes have certain common features, i e. one side of the membrane in contact with the fluid containing two or more components is more permeable to a particular (or like) component than the other components The other side of the membrane receives the permeating component after transfer through the membrane in a concentrated form Pore size &

pore size distribution plays an important role in determining the transport phenomena & the ultimate quality of the product. On account of very high costs of the membranes, such attempts have been made only on laboratory scale.

Ozonisation

Ultra-Violet Irradition

Membrane Filtration : Microfiltration (MF); Ultrafiltration (UF); Nanofiltration (NF); Reverse Osmosis (RO).

Advanced Treatment Technologies and Equipment:-

Lemella Clarifiers / Reactivator clarifiers
Continuous Sand Filters
Reverse Osmosis Membranes
Oil Skimmers
Biofloc
Non Clog Fine Bubble Diffusers
Belt Filter Press
Tunnel Reactos
Improved Equipment to Concentrate the Effluent;

Rosco Type Plate Evaporator
Mechanical Vapor Recompression (MVR)
Improved Evaporators :

Kestner Long Tube/Rising Film/Falling Film evaporator
Alfa-Leval, Sweden's Evaporator
Vogelbusch, Austria's Evaporator

Improved Equipment to Incinerate Effluent :

NEM - Vinasse Boiler of HCG, Holland
Vinasse Combustion Boiler of Kinetic Technology International, Netherlands
Sprannitherm Furnace of Thermax Ltd , India.
Others

AIR POLLUTION

The sugar factories generally run bagasse based boilers, which is rather a clean fuel compared to coal & furnace oil. The major pollutant in the flue gases is the unburnt fuel as SPM. A study revealed that very little information is available with respect to monitoring of stack gas emission & its control. A typical stack gas analysis of a 6000 TCD factory suggests it to contain 0.1 mg/l Sulphurdioxide, 2.0 mg/l nitrogen oxide, 300 to 1700 mg/N cu. meter SPM, 10% carnondioxide and 0.1 to 0.2% carbonmonoxide. Central Pollution Control Board has evolved standards for bagasse fired boilers suggesting a SPM content of 250, 500 and 800 mg/N cu. meter for stepgrate, horseshoe and speader stoker boilers, respectively. Different air pollution control devices used by the sugar factories to curtail SPM content of flue gases include air duct with cyclone catcher, cyclone arrestors. Dust collecting system, flyash arrestors, monoclone type mechanical dust collector, multiclone types dust collector, soot trap and dampers, vertical cone type flyash arrestor and wet scrubber type flyash arrestor. The use of bag filters & ESP's in sugar industry is not yet known possibly due to their high costs. Some factories in Punjab are reported to have successfully controlled water & air pollution with the help of water scrubber type flyash arrestors.

Following air pollution control devices are available :

Flyash Arrestor/Dust Collectors/Cyclones
Wet Scrubber Type Flyash Arrestors
Bag Filters
Electrostatic Precipitators (ESP's)

CONCLUSION :

A large number of envirofriendly clean technologies are available to sugar & allied industry for water & air pollution control, which may be used to eliminate/reduce the pollution, however, the choice will depend on a number of factors.